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EXPERIMENTS ON FLIGHT.

In order to ascertain in what measure man can raise himself with wings, in calm air, by his own strength, I have constructed from canvas, bamboo, and sticks a pair of wings which have a spread of 40 feet, and the form of which is that suggested by Mr. Marey in his valuable study on the flight of birds. Attached by straps to a wooden rod that connected me with the axis of the apparatus, I have been able, through the play of my legs and in exerting my entire strength at my ease, to lower these wings through the intermedium of wooden arms maneuvered by ropes. The same motion was communicated to the axis in order to render the plane of the wing oblique during the rising of the latter. The canvas of the wings consists of strips 4½ inches wide, which open like the feathers of a bird or like the slats of Venetian blind during the rising of the wing. These strips are held back on top by a netting, and each laps ¾ of an inch over the other, and beneath there are bands that limit their downward motion.

A series of experiments was performed between 1873 and 1881. In order to study the subject with perfect safety, I connected the apparatus by a safety rope with a cable stretched between two high poles on a prairie opposite the sea at Mont Redon on the Mediterranean.

With these movable wings well balanced, operating without effort, and suspended from a rope connected with the cable, I ascertained that man can cause but a relatively slow flapping of the wings, and one quite insufficient to lift him. With the least breeze, the apparatus easily rose; and with a wind of 30 feet per second, it reached the level of its point of attachment, which was about 60 feet above the surface (Fig. 1). Upon bracing himself on firm ground, man jumps and rises; but if the point of support be soft, and there be no spring to it, the jump becomes difficult. Immovable and free air is a springless bearing point which slips away from one.

I endeavored to take advantage of the experiment that I have just described by relying solely upon the force of the wind. To this end, I converted the preceding apparatus into a stiff plane of whole canvas, and, suspending it like the other from a safety rope, made it operate in the wind. This time I experimented on the hills of the vicinity, my cable being stretched over a gorge 480 feet deep and about 1,300 feet wide. Two high summits afforded me strong points of attachment. In order to allow me to vary the position of the center of gravity of the apparatus, and consequently the inclination of the plane, I used ropes; and I oscillated at my pleasure in a current of air of from 25 to 30 feet velocity, while the cable remained floating. Fig. 2 shows my apparatus thus raised by the wind. It was an experiment *in situ* and in air in motion, with a properly ballasted plane, left to a free fall in calm air, with the advantage that I had the arranging of the inclination and orientation of the apparatus.

Useful observations may be made upon such motion with a simple, thin cardboard disk (Fig. 3), 10 inches in diameter, provided with three sticks—two toward the edge, and a longer one in the center—each held in place on top by a pin or wire, and connected beneath at a point where, for ballast, one or more coins are attached by a rubber band. As the center stick is more or less inclined, it places the ballast more or less in front, and, when the apparatus is allowed to fall freely, thus permits of retarding the moment at which the plane (whose course tends to become horizontal) rights itself in the wind and procures resources whose failure causes it to fall back.

Thus man finds a resistant point of support, and sustains himself upon a current of air at right angles with the direction of gravity. He might perhaps fly by starting from such dynamic equilibrium. It is observed that birds can rise in space without flapping their wings, by describing, at high speed and with wings extended, a wide helix of a very short pitch. Desiring to place man under such conditions of nearly horizontal velocity, I suspended the above-mentioned plane from the cable stretched between two hills, and found it possible, after some swinging, to obtain a circular motion in which I felt a sensation of a notable lightening of my weight. The experiment is illustrated at the lower part of Fig. 2. It would then have required the least stress to lift me in the air, my purchase being taken upon a number of molecules (on the horizontal instead of vertical line, as in the vertical fall) so much the greater in a given time in proportion as the horizontal velocity was greater. But the circle that I tried was relatively too contracted to allow my apparatus of a few yards diameter to move regularly and with ease.

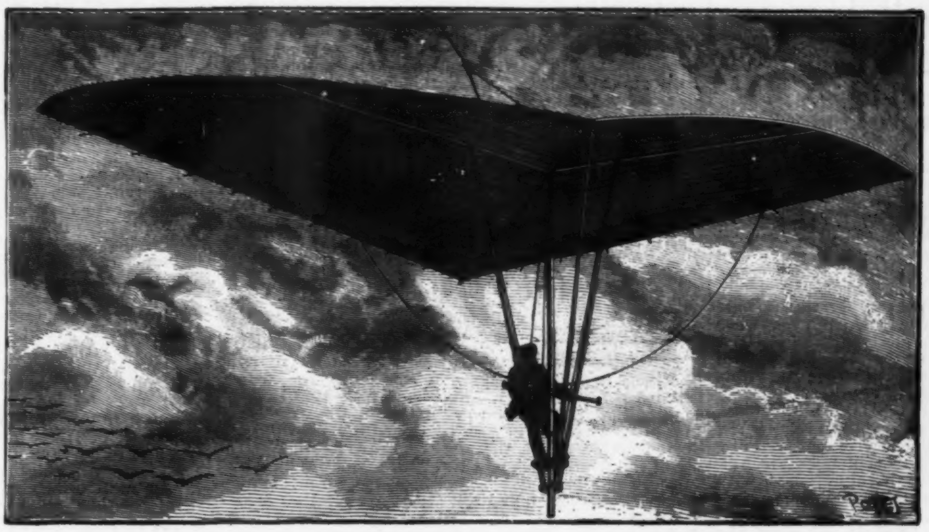


FIG. 1.—DE SANDERVAL'S FLYING MACHINE.

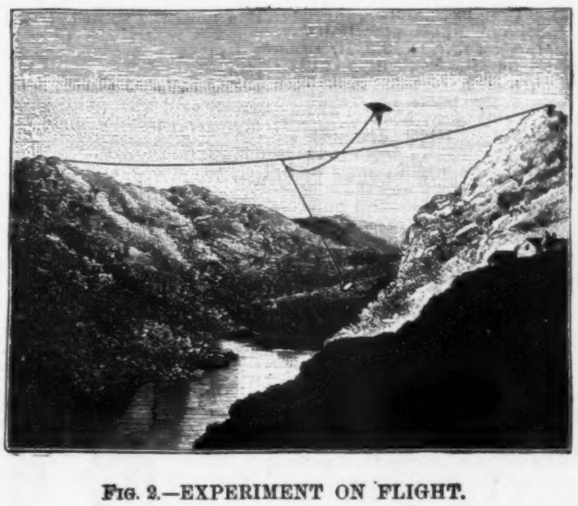


FIG. 2.—EXPERIMENT ON FLIGHT.

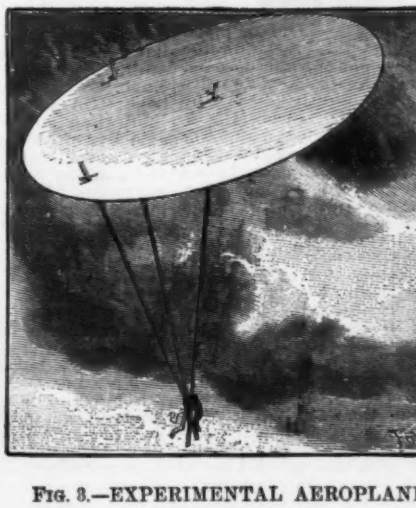


FIG. 3.—EXPERIMENTAL AEROPLANE.

On mountains one might stretch a cable several hundred feet in length over a deep valley, and, suspended from it, effect an independent flight through a combination of a hovering motion and a normal stress. Awaiting the invention of a light motor, I believe that the solution of the question is in the latter.

It may be of interest to note the following result given by the same rigid plane swiftly launched into calm air. The apparatus was attached near two large channeled pulleys placed one behind the other upon the cable, and forming an easily rolling carriage.

Thus suspended, and ballasted with a weight of 175 lb., the apparatus, stationed in the center of the cable, produced a deflection of several yards, which was easily measured by its projection upon the opposite mountain. Brought back to the higher end of the cable, and there left to the action of its own weight, it ran along the sloping cable with a rapidly increasing velocity. It was interesting then to observe that the deflection produced at the moment the apparatus was passing the center of the cable was nearly null, and was proportionate to the speed that I obtained to a greater or less degree by varying the height of the starting point. I have many a time detached the apparatus during this motion, in order to study its travel during a free fall. Every time, when the least displacement of its center of gravity occurred, it abruptly inclined, and was shattered on the ground, but not without having traced some interesting oscillation in space.—*M. De Sanderval, in La Nature.*

[Continued from SUPPLEMENT, No. 574, page 9172.]

FRICTION.*

By Professor H. S. HELE-SHAW.

Lecture IV.—Delivered February 8, 1886.

THE METHODS OF REDUCING THE RESISTANCE OF FRICTION.

EXTENSIVE and numerous as are the useful applications of friction, and indeed absolutely necessary to our very existence, we have only to remember that no motion of material things can take place without causing friction, and that all friction not directly useful is directly prejudicial, and therefore represents a waste of power, to realize that the question of its reduction may be almost as important and wide as that of its utilization.

The earliest device employed to reduce the resistance of friction probably resulted from the discovery that it was easier to roll than drag those bodies which otherwise were difficult to move. The next step would be made when it was found that the more closely a body approached the circle in section the easier it was to roll, and that heavy bodies which could not, from the nature of their shape, be themselves rolled along, might be made to move more easily when placed upon rollers. The body itself, under these circumstances, moves faster than the rollers beneath, and we find that Vitruvius attributes to Ctesiphon the invention of large hollow rollers, within which the body itself was placed, a device employed long afterward in our own times to launch the Cleopatra needle.

Long before the invention of Ctesibius an important modification in the mode of employing the roller had no doubt taken place. This modification consisted in transferring the point of support from the upper surface of the roller to its axis in such a manner as to entirely change the nature of the contrivance. The efficiency of the simple roller had been due to the fact that motion was imparted by means of what I have in the previous lecture called "statical contact." The modification in question, which was rendered necessary in order to connect the roller with the body to be moved, by means of what really corresponded to the frame of an ordinary vehicle, involved a certain amount of "sliding contact." But although sliding contact was thus employed, not only was its extent considerably reduced by the device of the wheel, but the progress which had been made in mechanical arts enabled the surfaces between which this sliding took place to be selected and prepared, so that the resistance of friction was as small as possible.

References to the use of wheels frequently occur in the earliest books. There are many such in the Scriptures, and in Assyrian, Egyptian, and Chinese writings. Reuleaux quotes from the earliest Indian literature of the Vedas, 1,700 years before Christ, in which mention is made of wheels in such a way as to show that they must even then have been of great antiquity. In Homer the heroes ride to battle in chariots; and my colleague, Professor Rendall, tells me that in archaic Greek writings the three distinct stages of the growth of the wheel can be traced, from the solid disk to the rude wheel built up of planks with its rough axle, such as may still be seen in various parts of the world at the present day, culminating in the elaborate arrangement of spokes and tire, the construction of which

* Lecture recently delivered before the Society of Arts, London.

forms the subject of such an elaborate description as to prove that the wheel had, even in the early days of Greece, been brought to a state of great perfection.

Now in the wheel we have two distinct principles, by the application of which the resistance of friction is reduced, these being—

1. The substitution, as far as possible, of statical for sliding contact.

2. The preparation and choice of suitable materials of contact.

This is so, not only in the wheel as applied to purposes of locomotion, but in its countless applications in the arts, from the fly wheel of the largest engines to the scape wheel of the smallest watch. Not only is this so where the wheel is employed, but in all cases where the friction of moving parts has to be reduced. Thus we see the same two principles employed in the most delicate balance, where a keen knife edge of the finest steel rests upon an agate bearing, as well as in the massive machine for testing the strength of metals, where a force of 300 tons has to be sustained by a knife edge which, though of increased proportions, acts in a similar way to that of the chemical balance.

These are the two principles in the applications of which heavy structures are made to rotate easily by being placed upon a "pivot."

The annexed figure represents the pivot of the swing bridge over one portion of the floating harbor at Bristol. When the bridge, A A, is required to be

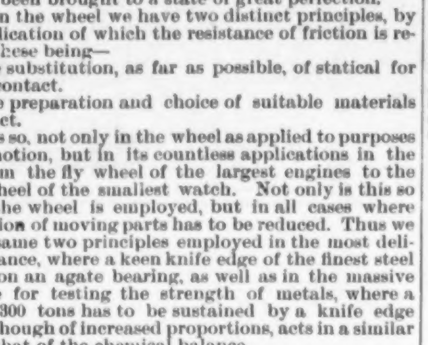


FIG. 60.—PIVOT FOR SWING BRIDGE.

turned, the hydraulic ram, R, working in the cylinder, C, is raised, and the weight of the bridge, which usually rests upon other supports, is thus brought upon the pivot. The actual pivot is the steel hemisphere, B, which turns in a socket made in the top of the ram, R (which ram does not itself turn). With olive oil as a lubricant, the bridge weighing about 150 tons is easily and rapidly made to rotate.

But in a variety of more homely examples we see these principles employed; thus in the hinge of every door or cupboard we have a simple, but beautiful, contrivance, by which the sliding contact is reduced to a minimum, the most suitable surfaces being at the same time used where such contact is unavoidable.

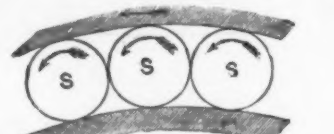
In this way examples might be multiplied indefinitely, and we should find that in all attempts to reduce the friction of solid bodies, and in all contrivances for doing so, either one or both of these two principles are universally employed; and I shall, therefore, deal with the subject of this lecture under two heads, corresponding to methods depending upon their respective application. It is well to remember that, in all cases, the reduction of the reaction between the surfaces tends to reduce the friction between them, and this reduction of pressure is naturally insured as far as possible. Thus the pressure on the pivot of a Fourneyron turbine is diminished by the employment of a shield or plate, suspended by a hollow cast iron tube inclosing the vertical shaft, so that the full weight of water does not act upon the revolving turbine. Again, the slide valve of a steam engine is often partially "balanced" by means of a ring which is fixed upon its back, the interior of which, communicating with the condenser or with the external air, prevents the pressure of steam acting over the whole valve area, and thus obviates a large portion of the waste in friction which would otherwise occur. The reduction of the weight, or whatever may be the cause of the pressure which causes surface reaction, is, however, such an obvious step that I need say no more about it. Before proceeding to consider in detail the mechanical contrivances for reducing the friction of solid bodies, I may point out that the reduction of fluid friction does not need special consideration in this lecture. It is, of course, highly important to bear in mind the facts and laws concerning fluid friction, which have already been set forth in the second lecture, in order to insure the minimum resistance in such cases as the flow of water through pipes or the motion of a vessel through the water. As a rule, however, no special devices or mechanical contrivances are employed to reduce liquid friction, which is in fact relatively so small compared with that of solid bodies as to be applied, as we have seen, under the form of lubricants, between surfaces of the latter to reduce their sliding friction. In the case of gases the friction is still less, and is neglected to an extent which may not always be expedient. Thus M. Ricour, chief engineer of the rolling stock on the French railways, gives an account of shields for the engine, applied with the object of reducing the resistance of the air, and also of coverings for the spaces between the carriages fitted for the same purpose; and when we remember that the effect of the wind upon a fast train is an important item in the gross resistances, we may yet see such devices more generally adopted.

(1.) THE SUBSTITUTION OF STATICAL FOR SLIDING CONTACT.

We have already noticed that a body resting upon rollers travels faster than the rollers themselves, and therefore continually changes its position relatively to them. When the motion takes place in a straight line, the body must ultimately leave the rollers behind, and thus, as we are all aware, in moving a load in this way it is usual to carry the rollers to the front as fast as they are released behind. If, however, the body is of cylindrical form, and the rollers are sufficient in number to encircle the cylinder, it is easy to understand that, by arranging a suitable case or frame to keep the rollers in position, continuous rotation of the body may take place. If, instead of a ring of rollers, one or more rings of balls be used, with a suitable contrivance to prevent their lateral motion, the same result is attained, and we thus see the principle upon which roller bearings and ball bearings act.

Now, before proceeding to discuss these two classes of bearings separately, we must notice a theoretical defect common to both classes, which when they are subjected to heavy pressures becomes of practical importance, though otherwise it does not seem, from actual experiment, to be worth taking into consideration. Fig. 61 represents an end view of a portion of a roller or ball

FIG. 61.



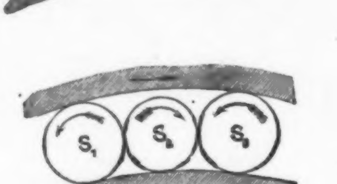


FIG. 62.

DIAGRAM OF BALL OR ROLLER BEARINGS.

bearing, showing three rollers or balls, S S S, between the two surfaces. If these rollers or balls all turn in one direction, their sides in contact must move in opposite directions, as will be seen from an examination of the arrows in the figure. Two methods have been adopted of remedying this defect, (i) by keeping the balls or rollers apart, (ii) by making the diameter of every other ball or roller smaller than the others. The effect of this latter device is seen in Fig. 62; here the middle roller or ball, S_2, not being pressed between the two surfaces, is free to roll by contact with the sides of the full sized rollers or balls, S_1 and S_3, on either side, and now turns in the opposite direction to that which it formerly did, as shown by the arrow in the figure, consequently there is no sliding contact of the balls or rollers against each other.

It must be noted that the term "roller" is applied to what are really small wheels, such for instance as are placed under the outer ends of dock gates to relieve the pressure upon the vertical hinge post, as well as to circular bodies where the surfaces which are moving relatively to each other are in contact at the two extremities of a diameter. Now it is true that in both cases rolling takes place, but the use of the same word to signify what are in reality two different things is objectionable, and I therefore venture to suggest the use of the word "roller wheel" for a small solid wheel supporting a load, and "roller bearing" for an arrangement of rollers such as I am about to describe.

Roller Bearings.—The roller bearing is a very old device, but though brought forward from time to time variously modified in detail, it has never come into general use, at any rate for continuous wear with heavy pressures. George Stephenson tried an invention of this kind by a Mr. Brandreth, during the construction of the Liverpool and Manchester Railway, but without any satisfactory result. In 1859, M. Brussault, of Paris, described before the Institution of Civil Engineers a form of roller bearing, the title of his paper being "On a new system of axle boxes not requiring lubrication and without liability to heating." The axle box of this inventor was specially designed for railway carriages, and the main feature was the use of India rubber bands for the purpose of keeping apart the rollers. Models worked very well, and these bearings were actually tried for a time in several mills, in one case to the shaft of a steam engine of 12 horse power, making from 450 to 500 revolutions per minute, in which instance, though no grease or lubricant was used, the bearing remained cool and worked so freely that the shaft continued to revolve for three quarters of an hour after the motive power was withdrawn. M. Brussault recounts a list of various other unsuccessful roller bearings, dating from 1825, and explains the reason of their failure, but as nothing more was heard of his own bearing, that must now be added to the list.

For certain purposes, where the motion is slow or intermittent, and the pressures are great, roller bearings are often used. Thus Fig. 63 represents the door of a cotton press weighing 5 tons; A is the door and B B the vertical axis, round which two rings of roller bearings (RR, RR) are placed. It was found that it took four men to turn it round. The weight was, however, partially supported upon the collar shown in the figure, and it was decided to place a ring of balls (S S) to assist in reducing the friction due to the weight of the heavy door. The result was that a weight of 35 lb., suspended over a pulley, was found quite sufficient to keep the door moving, and one man could work it easily by himself.

It is obvious that, though a ring of cylindrical rollers could not have been used beneath the door in Fig. 63,

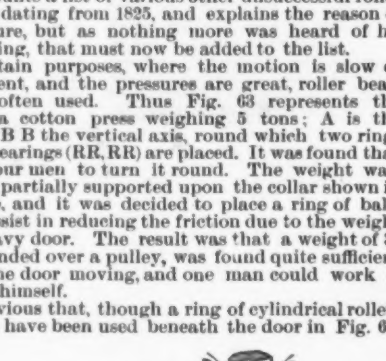


FIG. 63.—ROLLER AND BALL BEARINGS.

conical rollers might have been employed. Such conical rollers were at one time extensively employed in the United States to support the pivots of swing bridges and also for railway turntables. A cast iron disk had a circular groove turned in it to receive a number of steel rollers, each turned to the frusta of a double cone. A circular railway, 30 feet in diameter, was laid round the pivot for a turntable 48 feet in diameter, this railway only coming into operation when the table is not balanced on the pivot which is supported by the conical rollers. With a weight of 14 tons balanced upon one of these bearings, the whole was revolved by a weight of *three and a half pounds* hung over a pulley by a cord attached to the periphery of the turntable. The table is turned with heaviest engines upon it by the mere pressure of the hand, and without gearing of any kind. Pivots of the same design were fitted to two bridges each 230 feet long, and covering two openings of 100 feet each, one at Galena and the other at Chicago.

Roller bearings have had a most important application in bicycles and tricycles, where the pressures are comparatively light and the motion continuous. Though they have been to a great extent superseded by ball bearings, I will briefly describe a few of the more important forms, for an account of which, and also of the ball bearings for this purpose, I am indebted to the "Bicyclist's Handbook," by Mr. Henry Sturmey, which contains illustrations of many different kinds of such bearings. The action of the rubbing of the rollers against each other has, as I have already said, been found to detract to only a very slight extent from their effective action; but when wearing of the rollers takes place, it becomes an evil of a very serious kind, and hence various modes of adjustment have been adopted.

The simple device of having the case or framing in which the rollers are held made in two halves is not a satisfactory means of adjusting for wear, since the circular form of the case is soon lost, as the two halves are screwed closer together, and this is also the case with the Hughes roller bearing, in which a flexible split steel case, which can be adjusted by means of a set screw, is inserted in the outer frame, so as to contain the balls.

The entry of dust and grit into bearings is a serious evil, as will be seen from some results hereafter given, and special devices are employed to prevent this, as far as possible, from taking place; thus in Plowright's "dust proof" bearing the rollers are contained in a steel box with collars at each end, the whole being inclosed in an outer casing of steel. The dust is kept out upon the hub side of the bearing by this casing, which runs in a recess in the flange of the hub of the wheel, while on the crank side a second steel casing is fitted over the outside of the first, which forms a cap, and covers the boss of the crank.

Gubbins' cone and ring bearing has high testimony in its favor. Coned rollers are used, and both axle and axle box are plain, as for ordinary roller bearings, and an outside cap screws on laterally. Inside the case are two rings of round steel, one being on each side, and the rollers between; the outer cap is screwed up in order to adjust the bearing, and thus the rollers are pushed tighter against the axle and the outer ring. The rollers bear the friction at one point of their coned ends, and thus the rubbing which would take place on account of varying velocity ratios is avoided. The dust is excluded by means of a flange between the axle box and screw cap.

Silbert, Gadsby, Starling, and others have roller bearings of more or less efficient design. In that of the last mentioned maker, the axle is provided with a wide steel collar turned upon it. The rollers are of two kinds, the first being long and narrow, having the ends nearly twice as great in diameter as their central position. These roll, with their larger portions, upon the axle itself, and at the same time touch with their smaller portion both the turned steel collar and the case. The smaller rollers are placed between the larger and keep them apart, and the friction is thus considerably reduced.

There are few cases, if any, where balls cannot be substituted with advantage for rollers, which latter, however carefully made, cannot be so satisfactorily hardened as always to wear uniformly, and when worn unequally are apt to get "across" instead of remaining parallel to each other, and soon destroy the bearings, in spite of all contrivances for their adjustment.

Ball Bearings.—Although ball bearings have in some cases been applied where heavy pressures have to be sustained, their most extensive and important application is in connection with bicycles and tricycles. As in the case of roller bearings, the two great difficulties originally encountered, viz., that of adjustment and dust proof properties, combined with ease of lubrication, seem to have been most satisfactorily overcome. There are a variety of forms of ball bearings, but probably that best known and most popular is the "Æolus" bearing of Bown. Fig. 64 shows the exter-

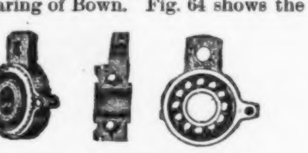


FIG. 64. FIG. 65. FIG. 66.

"ÆOLUS" BALL BEARINGS.

nal appearance of this admirable invention. Figs. 65 and 66 are respectively end and front sectional views. From Fig. 66 it will be seen that twelve balls are fitted side by side, and rest upon a conical groove in a steel collar which fits the axle, the collar being fastened to the axle by means of a set screw, of which the point is shown in the figure. From Fig. 64 it will be seen that a collar is screwed into the main body of the case, having a coned end corresponding to the coned portion in the case, and the ring of balls is, by the action of the two cones, forced closer to the axle, and thus adjusted in any required manner. In Fig. 64 is seen the milled or toothed edge of the collar by which this adjustment is made by hand, the teeth of this edge at the same time enabling the adjustable portion to be locked in its place by means of another set screw shown upon the side of the bearing. Rudge's bearing is very similar to Bown's, but there are only nine balls, and the set screw which holds the adjusting plate or collar in its place is fastened to that collar. Whitehouse's and the Stanley bearing are similar in principle to the foregoing; the

Club bearing, in addition to the use of two coned surfaces, is adjusted by means of a set screw, which draws together the two sides of a division made in the otherwise solid case. Hough, Green, and Granger are all inventors of ball bearings which are chiefly remarkable for their simplicity and cheapness, in which, as in all the bearings previously mentioned, there is only one ring of balls, known as single ball bearings. Double ball bearings are now much in request, from the additional steadiness thus secured in running. Humber's bearing is an example of the latter kind, the balls being kept from rubbing against each other by means of a light frame in which they are placed, this frame simply consisting of a thin cylindrical collar pierced with holes, in which the balls just fit, and which is carried round with the latter. There are many other forms of double ball bearings, such as Hillman's, the Sandringham, the Club, the Rapid, etc., each form having some special points of interest and ingenuity.

It would take too long to treat this interesting subject with anything like the fullness it deserves, for not only are ball bearings employed for the main wheel of the bicycle, which is the purpose of all those to which I have alluded, but for the smaller back wheel, for the pedals, and even for the bearing between the head and the solid portion connecting the forks and handle. To illustrate the extent to which ball bearings have been applied, I may mention that in the parts directly connected with *one wheel* of a small bicycle of the safety type (which, together with others in the room, I am enabled to show you through the kindness of Mr. P. Louis Renouf), there are no less than 144 hardened steel balls for diminishing the frictional resistance of the various parts.

That a very small amount of wear takes place when ball bearings are properly managed is well known, but this subject has only been actually investigated a short time. Mr. C. V. Boys has recently given the results of some measurements made by him upon the actual wear due to friction taking place in such ball bearings. At the end of every 200 miles run he cleaned the balls, and then weighed them with all the possible care and accuracy that the resources of a physical laboratory would permit. The set of twelve when new weighed 25·80400 grammes, and after running 1,000 miles they weighed 25·80088 grammes, the loss being 3·12 milligrammes, or *less than $\frac{1}{20}$ of a grain*—that is to say, each ball in running 1,000 miles lost *only $\frac{1}{240}$ of a grain.* This corresponds to a wear of only $\frac{1}{1250000}$ of an inch on the surface. Thus, at this rate of wear, the balls would lose less than $\frac{1}{4}$ of their weight when in use in traveling as far as from the earth to the moon. Further experiments have been since made by Mr. Boys, in which the balls were not taken out for the whole distance of 1,000 miles. The balls actually showed only $\frac{1}{4}$ of the wear above mentioned, from which it would appear that the wear due to such grit and dirt as cannot be entirely excluded at first, but which does not get in after the bearing is properly screwed up, does not continue after the dirt is ground up, after which the balls literally *do not wear at all.*

These astonishing results point to the fact that ball bearings have a high mechanical efficiency; and it is extremely probable that as the cost of their production becomes less, and the mode of accuracy and quality of their manufacture improves, they will be employed not merely, as now, for the occasional use in such cases as for the foot of crane posts, but for many other purposes on a large scale, such, for instance, as in the thrust bearing of screw steamers, and possibly even to carry the shafting itself.*

The rubbing, or friction of sliding contact, which occurs in the various examples of roller and ball bearings that I have mentioned, takes place either from the mutual contact of the balls or rollers or from their contact with some other portion, such as the cylindrical frame in the Humber ball bearing. In these cases, although true rolling takes place between the surfaces transmitting the actual pressure of the load, sliding contact is an unavoidable accompaniment. One principle of the wheel, as I have already explained, consists in the reduction of sliding contact between surfaces which transmit the pressure of the load. Now this sliding contact, which must always exist, may be reduced to as great an extent as desired by increasing the diameter of the wheel. The size of the wheel is, however, in most cases limited for reasons of a practical nature, but the same principle can be applied to an indefinite extent in the following manner: Suppose that the practical limit of the diameter of the wheel be reached, and that its axle be made as small as possible. Instead of allowing this to rest in a bearing of the ordinary type, where sliding contact would occur, let it rest upon the upper portion of the circumference of two wheels whose axes are parallel to each other and are in the same horizontal plane, but do not coincide. The axle of the first wheel will now roll upon the circumference of the other two, and the sliding contact will be less than what it otherwise would be in the proportion of the circumference of the pair of wheels (in which the axle now rolls) to twice that of their axles (because there are two of them). Thus, suppose the sliding contact reduced to $\frac{1}{50}$ of its amount by the first wheel, and that the axles of the so-called "friction" wheels are half the size of the axle of the first (for there are two to sustain the load), while their diameters are the same as that of the first. Then the amount of sliding contact which finally occurs is only $\frac{1}{50} \times \frac{1}{50}$ or $\frac{1}{2500}$ of the amount which would take place if no wheels were employed. This principle is employed in the well-known Attwood machine, and it has also been used for supporting the crank shaft of small foot lathes, but it has not been found suitable for application to heavy machinery. In the latter case, if the lubrication of the axles of the "friction" wheels is neglected, and the axle of the primary wheel cannot turn the former by the frictional upon their peripheries, then at their common point of contact there is, as in an ordinary bearing, sliding contact; and when once the groove which is certain to result from this action is cut in the peripheries of the friction wheels, their successful action becomes altogether impossible, and they must be replaced. Thus, although the principle is a beautiful one, its application is confined to philosophical apparatus and purposes where the working pressures are not great.

(*To be continued.*)

* Since delivering this lecture, I have seen for the first time an account of the actual application of ball bearings to this purpose (*Engineering*, Aug. 6, 1886, p. 122). Mr. Wells, of Northwich, Cheshire, more than 18 months since, applied a ball thrust bearing to the steam launch Delaware, the speed of the engines being in consequence increased from 177 to 187 revolutions, with the same boiler pressure and grade of expansion. A ball bearing was afterward fitted to the steam tug Volunteer with very satisfactory results. With a 5 inch shaft there are two concentric circles of balls employed, one pair for going ahead and one pair for going astern, and it is stated that the bearing requires little oil, that the wear is very slight, that there is in consequence no end play on the shaft, and that the first cost is moderate.

[Continued from SUPPLEMENT, No. 574, page 9162.]

[THE INLAND PRINTER.]

SOME TYPE WRITERS—THEIR ORIGIN AND USES.

By J. B. HULING.

AMONG the older residents of Milwaukee, Wisconsin, is Charles Latham Sholes. He learned the art of printing in his early life, and subsequently became an editor. At the close of the war he was the collector of customs at Milwaukee. He never had relinquished his interest in printing, and in 1866–67, with an old friend, Samuel W. Soule, was concerned in getting up a consecutive numbering machine, for putting the numbers on bank notes or on the pages of blank books after they were bound. Soule, also, had learned printing, but was then a farmer near Milwaukee. He had some reputation as an inventor, besides. Accidentally Sholes and Soule were thrown in contact with Carlos Glidden, who was an inventor, and was developing a model in the shop where the numbering machine was being put in shape. Glidden saw that, and casually remarked that, pursuing the principles there embodied, letters and words might possibly be made instead of figures and numbers. Neither Sholes nor Soule had ever seen or heard of such an invention (type writer), and they did not happen to be much interested by Glidden's comment. However, some time later, they saw printed an account of a type writer,* which closed with the information that there was a fortune in store for whoever first completed a practical and durable machine of that sort. They then considered the feasibility of adapting their invention to a similar purpose. Glidden was invited to conference, and mutual suggestions were interchanged. Months passed while the rough ideas were being moulded. A working model was made, but was only in a measure satisfactory. Early in 1868 Soule and Glidden ceased their connection with the enterprise, and Sholes was encouraged by the suggestions and financial aid of James Densmore of Meadville, Pennsylvania, a printer and editor. The first patent was secured in June thereafter, and a second one about a month later. From time to time sample machines were put together, and sent here and there to be tested by writers. Several years passed, meantime, but many valuable suggestions were received in the way of criticisms, and were profited by. The machine was thought complete enough in 1873 to make arrangements for its manufacture and general sale. It had received some advertisement among stenographers by the chances afforded for testing, and was known as the Sholes & Glidden type writer. A contract was made by the Type Writer Company, which had been duly organized, with E. Remington & Sons, of Ilion, New York, well known manufacturers of firearms, sewing machines, agricultural implements, etc., to make a number of the writers. They had them ready by the middle of 1874, and then the first type writer was really on sale. About four hundred were disposed of by the end of the year. Then it seemed that discouragements were never greater, but they were persisted against, and improved features were devised. The type writer was steadily becoming more popular. In 1876 it was well shown at the Centennial Exposition, and its advertising matter and samples of the work were scattered therefrom to all parts of the world. By the spring of 1877 about three thousand had been made and sold. Up to that time its general appearance was as shown in Fig. 2, except that the hanging arm on the right front corner was not attached. The paper carriage shown on top of the machine in the cut held a rubber-faced cylindrical platen to receive the impression, and round which the sheet of paper was conducted by rubber tapes and metal guides. It was moved forward by a cord connecting with a wheel in the rear left-hand corner, beside which was a coiled spring. It was hinged on a supporting bar at the back, and upheld in front by a wheel running on a planed way. Connected with the hinges was a ratchet feeding device, admitting of but once space forward action at a time, with each impression struck. The carriage could be raised to a vertical position at any time during the printing, and the work under it be examined or corrected. The return motion for printing a second line was made by a cord connection with a pedal, which rendered a special table necessary with each machine. A ratchet wheel on the right end of the cylinder regulated the lines as they succeeded each other. Capital letters only were employed, and impressions were made through an inked ribbon, which moved after struck, exposing a fresh surface for the next character. On the front of the frame of the machine, as shown in the cut, was a scale, over which hung a pointer from the center of the carriage frame. By this scale it could be seen always at what space in the line an impression was to be made, and adjustments could be more readily made for purposes of correction, determining margins, etc. The frame would not ordinarily receive paper over eight inches wide, and the printed line was an inch and a half less. The apparatus, independent of the table on which it stood, weighed about thirty-five pounds, and the greatest dimensions each way were about sixteen inches. The keyboard showed forty characters, but by several combinations a few more signs were available. For example, the apostrophe was ', and printing a . under it made !; and striking I across S made $. I was used for 1, and O for a cipher. A bar extended along the front of the keyboard for a spacing key. Manifold copies were made.

Fig. 2.

* The pterotype, invented by John Pratt, of Center, Ala. Pratt was living near London at that time. He showed his machine, and explained its construction and usefulness at great length before the Society of Arts, in 1867, reading a paper which was published in the *Journal* of that body. His patent in this country was taken out in 1868. From all that may be learned, it is concluded that the pterotype was complicated in design, and would not endure ordinary wear. The only ones made appear to have been for the personal use of the inventor.

It will be noticed that there was a remarkable similarity in the plan and accomplishments of this machine and Francis', described before; but the latter was excelled in compactness, durability, fineness of construction, and ease of operation, as much as the Remington model of to-day is ahead of its predecessor of ten years ago. The Sholes & Glidden machine had steel type inserted to rise vertically at the ends of bars depending from a circle, and slightly converging, and each type face was at an angle of its own, to print in line when brought to the platen. These type faces were cut especially to deceive the eye in their impressions, as each struck in an equal space, thick and thin alike, and the appearance of spacing words could only be avoided in that way. Scanning a page of type writing from top to bottom, or *vice versa*, will reveal the characters printed in columns. Fig. 3 is a section of the machine, showing the connection of the type bars with the levers proceeding from the keyboard, and the principles of the printing action. L is a wooden lever hinged at the back of the frame at its lower part. A is the end displayed on the keyboard, being a glass-faced cap covering the character, and offering a surface for the touch of a finger. W is a wire connecting the lever with a type bar above, which of itself is a lever fulcrumed close to the wire connection, and hangs as shown. T is the type in position. If A is touched, L is depressed, and T moves upward, following the direction of the dotted line in the diagram. A spring under each lever near its hinge forces the key back to its position after the touch is removed, and the type is correspondingly retired from the impressing point. R shows position of the inking ribbon, which passes from one reel to another, the motion being reversible when desired. S and N are merely other keys. J is the top of the frame, and C is the platen holding the paper, being stripped of its details, of course.

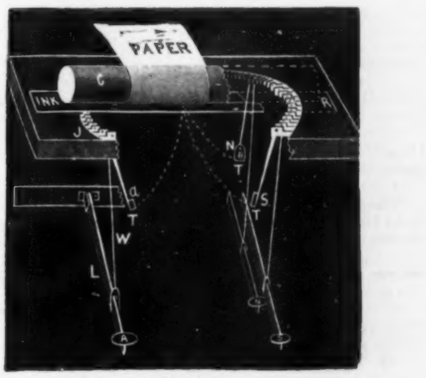


FIG. 3.

The Western Union Telegraph Company was early interested in the Sholes & Glidden machine, and secured control of it; but it was not then so useful to it as expected, and its rights were bought. Sale was intrusted to different general agents from time to time, one being Locke, Yost & Bates, comprising D. R. Locke, now of the Toledo *Blade*, and J. H. Bates, a New York advertising agent. Fairbanks & Co., the celebrated scale makers, also undertook to sell it for a time, subsequently, through their numerous branch houses. Then E. Remington & Sons themselves assumed the charge of sales, and their name thus became the more firmly identified with it. Since August, 1882, the control has been with Wyckoff, Seamans & Benedict, practical men, who formed a partnership for the purpose, and whose energy and business management, with most lavish advertising, have given an impetus to the type writer's sale only expected by the most sanguine in the early years of its manufacture.

The machine has steadily been improved, to make it more attractive externally, to increase its usefulness, and to stop the criticisms as to its durability and execution. The greatest amendment of all was in the application of a double set of characters, in 1877, thus enabling the printing of large and small letters. This was achieved without enlarging the bulk of the instrument in any direction, and at once won high favor. Each type bar in the circle was made to carry two characters, adjusted to separate common centers, and the cylinder platen was set in the carriage to move backward to a second center obedient to the touch of one of the keys. This device is now commonly known as the "shift," and is used chiefly for capital letters. The shift may be locked, to print all capitals, another key standing for a shift to any character on the lower-case center. Another change of great value was the abandonment of the old attachment for drawing the paper carriage back to begin a line, and the employment of the arm shown on the right-hand front corner of Figs. 2, 4, and 5. Grasping this arm works the platen ahead a space (it may be set to move two lines space, and print "open"), and releases the feeding ap-

paratus at the back of the carriage, permitting an easy movement to any point on the line.

Fig. 4 shows the general appearance of the latest pattern Remington. The double alphabet machine is known as No. 2, and the single as No. 4. The dimensions have been somewhat contracted, and are now fifteen inches front to back and side to side, and twelve inches in height, all extreme. The weight is diminished to twenty-three pounds. No. 2 prints a line of six and a half inches, ten spaces to an inch, and No. 4 the same, but five spaces more, each carrying eight inch sheets, and the one sells, as shown, for $95, and the other for $75. If put on an ordinary table to

FIG. 4.

be used, the keyboard is so high as to be unhandy to reach, and the work is more fatiguing; therefore, a low stand is made, and sold at an additional charge.

As the characters are practically part of the type bars, being driven tightly into their sockets there, they are not easily changeable. Anything specially required, in the way of style of letter or peculiarity of character, such as accents, etc., has to be ordered with the machine. For each machine four faces of type are regularly offered to be chosen from. The following are schemes of the keyboards, the idea of arrangement being the same as that of the printer's case, to have those used most frequently together near each other:

No. 2.

" ¼ $ ½ — & ' ( ) L. c.
2 3 4 5 6 7 8 9 - shift

q w e r t y u i o p

a s d f g h j k l : ;

U. c. ? .
shift z x c v b n m , %

Where there are two characters on a key, the top one is on the upper-case shift. The dash in the center of the top row is an underscore.

No. 4.

2 3 4 5 6 7 8 9 - ? $

Q W E R T Y U I O P :

| A S D F G H J K L ;

& Z X C V B N M , . '

The | on the left end of the second row from the bottom is for parentheses, braces, etc.

Fig. 5 represents a machine introduced in February, 1886. It is known as No. 3, and is distinguished chiefly

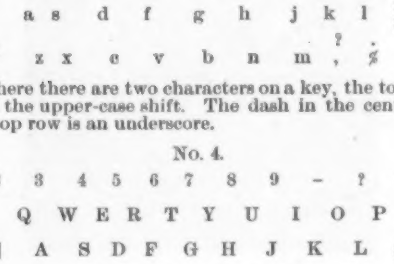


FIG. 5.

by its wide paper carriage, holding a sheet fourteen inches across, and printing a twelve inch line. The keys are increased to print, with shift, eighty-four characters. These include sundry commercial signs, marks of reference, etc. To support the enlarged carriage, the frame and other parts have been strengthened and modified in minor details. This wide carriage type writer is demanded in England more than here, for there the law requires many documents to be on paper wider than ordinary; yet insurance agents, abstract makers, and many attorneys in this country have felt the need, and will doubtless welcome the style. There may be three degrees of spacing between lines.

The Remington type writer, being the first in the field, is the widest known, and in most general use. The two leading commercial agencies of the country, Dun & Co. and the Bradstreet Company, require about five hundred machines each in their various offices, and probably derive more benefit from their use than any other single line. In the government offices at Washington there are a great many, and also in the offices of many State and foreign governments. Their sale abroad has been limited, partly because the mechanical construction will not easily admit of the substitution of all alphabets, somewhat from the more conservative methods pursued by the business men there, but chiefly, no doubt, because the sales in this country called for nearly all that could be made. Increasing competition has stimulated the greatest efforts toward perfection, and what is offered as the 1885 model reduces criticism to a minimum. It is manufactured under a number of patents covering its combined features.

Among the many gentlemen whose attention was called to the Sholes & Glidden type writer in the years between its invention and general sale was George W. N. Yost. Mr. Yost had taken out a number of patents within the fifteen years or so preceding, and under them several very successful agricultural implements were being manufactured. He was ambitious and full of enthusiasm, and saw great possibilities for the type writer. He became interested in it in a pecuniary way, and was one of the parties bound by the first contract with the Remingtons. He was in the factory a great deal during the execution of that contract, and gave the benefit of his wide experience with other inventions, contributing largely thereby to the moderate measure of success had. Building type writers seems to be an art by itself, and, to be practiced well, it has to be acquired by special experience, not through general familiarity with machines; every inventor, therefore, finds extreme difficulty in getting his apparatus constructed in quantity, even after he has made many single examples. At a later period, Mr. Yost was one of the firm of Locke, Yost & Bates, mentioned before, and took an active part in making a market for the type writer. While thus engaged, he naturally came in contact with many of those who were trying the machine, and became forcibly impressed with the value of much of their criticism. From time to time he made various suggestions for improvements, some of which were accepted, and others were not. Believing that the manufacturers were too slow in listening to all the demands for better working machines, he severed his associations with the type writer, and started on plans for something new. Some of his designs then followed in the type writer he secured the right to use further, and he put them with his fresh ideas, and worked out a writing machine he called the caligraph. (Fig. 6.) The principal patent was taken out in 1879, and several years passed before the sale of the machine was begun. Comparison with its predecessor and now competitor is unavoidable. The resemblance is so great at a casual glance that the differences are not noticeable, yet there are many. The caligraph was made with a lighter frame, and in two sizes. The shift was done away with, and the double-case machine was provided with a separate lever and type bar for each character. The paper carriage motor was entirely new in design. The levers were hinged at the front of the frame.

FIG. 6.

The caligraph was welcomed, and its advent was a stimulus to improvements in the Remington that would seem to have waited for competition to develop. The caligraph established lower prices at first than now. Essentially it was and is the same as the Remington, and theoretically both machines should have the same degree of popularity. But whatever the experience of its inventor in the manufacture and sale of the type writer, it did not avail him all he expected in making and selling the caligraph, and that instrument became the subject of severe criticism on its own account, and the trials and tribulations of reducing fault finding were manifold. The property was with a corporation called the American Writing Machine Company, which established its own shops at New York (removing afterward to Corry, Pennsylvania, and more recently to Hartford, Connecticut), and set about vigorously to overcome the perplexities seemingly inseparable from the building of every type writing apparatus. Through time, patience, and skill, the defects complained of have been obviated, and the machines now offered seem to give all reasonable satisfaction. The general design of the caligraph has never been altered, but in the details of its construction there have been numerous modifications to make durability and exactness of work more certain.

Two sizes of the caligraph are made ordinarily, the single case (No. 1) and the double case (No. 2). The length of longest printed lines is seven inches, and the greatest width of paper carried is nine inches. Four faces of type are offered for No. 1, and three for No. 2, the larger faces printing fewer spaces to the line, as low as fifty-five in one case, but the line is not diminished in length, however. The impressions are made through an inked ribbon. Like the Remington, the caligraph is easier operated on a low desk. No. 1 has forty-eight characters, weighs about fifteen pounds net, and stands fifteen inches front to back, thirteen wide, and ten high. No. 2 has seventy-two characters, is about twenty-one pounds in net weight, and in extremes is eighteen, fourteen, and twelve inches, respectively. Of No. 2 there is an extra style with a wider paper carriage, holding a sheet of eleven inches and a half, and printing a line of nine inches and a quarter. Manifolding copies is practicable. No. 1 sells for $70, and No. 2 for $85. Somewhat more than 13,000 of the various styles have been made and sold to the present time, most of them being in daily use in different parts of the country.

The cut (Fig. 6) is of No. 2 machine. The difference of many of its features with those of the Remington may be readily detected there. But one style will not do more than the other in execution. They are designed for precisely similar purposes. The capital letter keys are black faced, and are at the sides of the keyboard. The space lever is depressed from the touching plates shown on either side of the keys. The space between the operator and the keys is occupied by the extension of the different levers to the hinging bar. The cylinder platen has a polygonal surface, the impressions being received on the faces. The bar in front of the cylinder holds the alarm bell slide and the stop slide for the left-hand margin. The carriage is supported and is adjustable, as in the Remington, but actuated by a torsion spring about a rod extending from the front to the back of the machine frame, where a vertical arm connects with the carriage frame above. The spacing for impressions is regulated by a double-sliding ratchet at the back of the paper carriage. The paper is guided over the cylinder by metal tapes.

Following are plans of the keyboards:

No. 1.

2 3 4 5 6 7 8 9

— Q $ (& Z) !

W T R E Y U I O

A S D F G H C K

J X V B N L M P

? : ; ' " . , —

The dash in the second row from top is an underscore, the lever for which is so cut that the carriage is not moved till the letter is also printed, it being thus necessary to underscore first.

No. 2.

V W 2 3 4 5 6 7 8 9 J K

R T E ($ q & z) U G H

A S w t r e y u i o I O

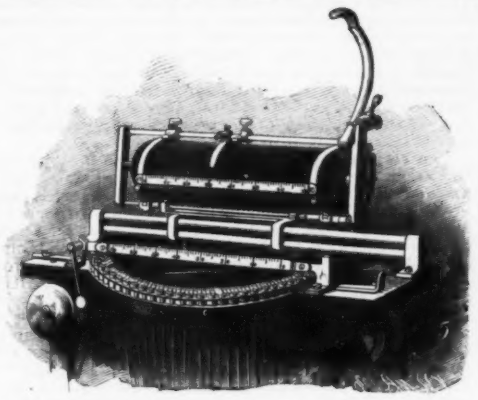
D F a s d f g h c k N L

B C j x v b n l m p M P

Q X : ; ' ? ' . , - Y Z

March 3, 1881, Thomas Hall, previously mentioned, was awarded a patent for one of the inventions he had in embryo when he put aside his type writer of 1867. (It is shown in SUPPLEMENT, No. 574, page 9162.) In nearly every respect it was a radical innovation on all previously known conceptions. It was greatly diminished in number of parts, in weight, and in its proportions; it embodied a most novel application to bring the characters to print at a common center; every machine was double case, either alphabet being available without appreciable effort to discriminate; the printing apparatus, instead of the paper carriage, moved the length of the line; rubber characters were employed, cast from printers' type, and different styles were offered at a very low price, and were interchangeable by any one almost instantly; there was no inking ribbon, but impressions took place direct from the type. More remarkable than all, however, was the fact that only one hand was required for the principal operations. Hall had previously secured the co-operation of a Boston capitalist, by whose aid full development was obtained, and subsequently patents were procured in many foreign countries, and arrangements made for manufacture and general sale. A company was formed, and a shop established in New York. For several years the distribution was moderate, pending positive settlement of all details. By the fall of 1883 three hundred machines or thereabouts had been constructed, when advertising was begun, agents engaged, and sales jumped up beyond precedent. In another

year, over three thousand had found purchasers. Then there was a slight slackening. Marvelously simple in design as was this type writer, and carefully as it was thought out before being offered in the market, notwithstanding, effective adjustments could not always be had in each machine; inequalities existed, and a season was taken to perfect the minor points of manufacture. Here, again, exposure to wide scrutiny



CALIGRAPH, WITH PAPER CARRIAGE RAISED.

revealed in a year what the inventor could not foresee in a decade of study in his closet. During 1885 there were not the facilities for making and selling previously had, but improvements were effected to an appreciable extent, and increased popularity found generally, so that when the current year opened, the number of instruments disposed of had nearly reached five thousand. The shops had meantime been removed to Salem, Massachusetts. The ordinary machine by itself is fourteen inches from side to side, seven inches from front to back, and three inches high, all extremes, and its weight is two and three-quarter pounds. Each machine is furnished in a wooden case, which supplies a base, and adds four pounds more to the weight. The cut shows the machine under operation. The frame is attached to the bottom of the case, but hinged at front, with a notched strip of metal on each side. Back of the frame is a prop, on which to elevate it to several positions, resting in the notches referred to. No special desk is required. The largest single feature after the frame is the printing carriage. This moves from one side to the other, and may be raised to a vertical position, hinging on the supporting bar at the head. The motion of this carriage from left to right is caused by a spring coiled in the small drum shown in the center at the head, this drum being cogged on the outside to fit in the notches of the supporting bar. The unwinding of the spring is regulated by blades in the upper right-hand corner of the carriage, which are held in the notches by an upholding spring inside of the carriage, but are freed (1) by depressing the top of the carriage, (2) by action of the spacer key (shown in the lower right-hand corner of the carriage), or (3) by being raised by the fingers at the grasping pieces above. To return the carriage from right to left, or to put it at any point desired on the line of printing, the fingers lift the blades, and control the coiled spring. The carriage is in two sections. The top has the letter dial on its upper side, and holds the printing plate underneath. This printing plate has seventy-two characters in a space two inches square, is elastic rubber, is cast in the same way that rubber stamps are made, and is held on a frame ingeniously jointed to enable the printing plate to be moved in any direction, and admit of any single sign in the square being at once drawn to a center. The letter dial is a hard rubber plate, about an eighth of an inch thick, perforated to expose under it impressions on a card to correspond with those in the printing plate. Surmounting the dial is a handle of hard rubber, having under its front a steel pointer resting in the perforations, and at its back being attached to a projecting bar from the frame holding the printing plate. In the center of the top of the carriage, in front of the letter dial, is a post, threaded, penetrating the top, and standing over the printing plate. This makes the impression when the carriage is pressed together, driving the character in the plate through a hole in the bottom of the carriage. This post may be turned to increase or diminish the impression. The bottom section holds a thin tin plate, on which is spread a thickness of cloth that is inked as may be required. This ink pad is perforated, of course, and on it all the characters in the printing plate rest at an impression, except the one printing, the entire plate being thus kept inked constantly. Moving the pointer over the dial draws the printing plate around under the impression post, and whenever in the dial the pointer is inserted and held, the character corresponding in the printing plate is brought and held below the post. The front of the carriage is held apart by props connected with a spring, and latched, so that it may be opened, and access be had to the printing plate or the ink pad. Putting the pointer over the desired character, and pressing down, effects an impression, and when the pressure is relaxed the plate is lifted, and the carriage is pushed by the coiled spring to a succeeding space. Right and left across the frame, and passing under the printing carriage, will be seen the platen to receive impressions. Upon this is an etched line showing where the foot of each letter strikes, and is a guide for printing on ruled paper. Under and in front of the platen is a rubber-faced roller, over which the blank paper passes. Against the front of this roller is a clip to hold the paper in place, and which is itself pressed by an adjustable screw extending back through the machine frame. The screw may be lifted in the orifice in the frame, and the clip is thus permitted to fall back and admit a sheet of paper around the roller from either front or back. At the left end of this roller, inside the frame, is a ratchet wheel, which is acted by the fingers on a suitable connecting lever, and moves the paper forward for a new line. Outside the frame, on the end of the roller spindle, is a button, whereby the paper may be moved backward or forward any required distance, independently of the ratchet wheel, and is graduated for exactness of position. The square bar from left to right across the head of the frame is the bell shaft. Beginning at the left is a scale numbered to seventy-four (ten spaces to an inch), which is duplicated on the clip over the roller carrying the paper. From the upper left hand corner of the carriage projects a pointer to the scale on the bell shaft. The adjustment is such that this pointer always indicates where on the line of printing an impression will fall. At the left end of the bell shaft is a stop slide for margin, and at the end opposite is an alarm slide, supporting a gong, inside which a hammer works by a cam connection with the carriage, notifying of the end of a line. The little finger works the space key, without hold being relaxed on the handle over the dial. The outside blade at the right hand of the carriage may be set with a single turn of a screw to jump two notches in the bar, and so space between letters and double between words, useful in headings and envelope superscriptions. Manifolding is successfully accomplished by hardening the face of the characters in the printing plate, or by setting on an elastic rubber sheet electrotyped faces. The change in the Hall, whereby the printing apparatus moves along the line instead of the paper, enables the mounting of paper in a web, and printing matter by the yard. Two sizes of the machine are made, one at $40, printing a line seven inches long and working paper twelve inches wide, and one at $50, printing an eleven inch line and carrying seventeen inch paper. Following is the plan of the printing plate:

1	2	3	4	5	6	7	8	9
(	&	;	"	-	?	¢	$	)
K	B	F	G	N	I	A	S	Q
J	C	D	O	E	H	T	W	V
X	M	Y	L	.	R	U	P	Z
k	b	f	g	n	i	a	s	q
j	c	d	o	e	h	t	w	v
x	m	y	l	,	r	u	p	z

The O is used for a cipher, and the , may be printed at the top of its space for an ', thus affording two extra characters. The printing plate is removable almost instantly for change of style, there being regularly offered a dozen faces or more, besides plates with characters for special purposes. They are sold for $1 each.

The Sun type writer is shown in Fig. 7. It was put on

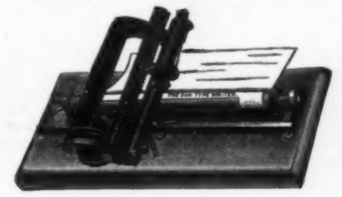


FIG. 7.

the market in New York in the fall of 1884, and is now substantially as it was then in construction and accomplishments. The apparatus is on a wooden base, weighing altogether four pounds and a half. It is twelve inches long, eight wide, and three and a half high, and holds paper eight and a half inches wide. Impressions are direct from the characters. An iron post holds the frame seen extending from front to back of the instrument, and on the front of this frame is a series of teeth; above and opposite the interstices between these teeth being displayed the characters in use, as may be plainly discerned in the cut. In front of the row of teeth is a groove, hinging at the back of the frame, holding a slide, and being perforated at several points on its underside. On the bottom of the slide is a row of characters electrotyped from printers' type, corresponding with those shown on the frame, as referred to. Attached to the top of the slide is a casting projecting over either side, affording finger hold on the right end, and on the left being filed to a knife edge beneath.

The slide works back and forth by application of the fingers, and the knife edge ranges over the teeth. The paper is inserted behind a kid-covered roller, and held against it by a metal clip in front and a wire above. It moves backward or forward by action of the fingers on the button shown at the right end. The roller stands on a simple frame, in ways, and having a ratchet connection in front with the frame above. Ink is supplied from several small felt rollers held at the perforations under the type slide. Printing is effected by depressing the groove, when the knife edge passes between the teeth under it and opposite the selected character, which appears at the perforation under the type slide and over the roller and impresses. The bearing down on the groove acts the ratchet connection, moving the paper a space to the left, and the groove is lifted by a common spring. But one alphabet is used and one style of type, and the price of the machine is $12.

Toward the end of 1884, a modest announcement of a type writer was made by McLoughlin Bros., the well-known New York publishers of toy books, valentines, etc. It is on a wooden base, is about twelve inches long, six inches wide, and five and a half inches high, weighing four pounds. The printing apparatus is in a carriage sustaining several disks, the lower of which rotates, and around its edge are the characters used, a single alphabet, figures, etc. They are electrotyped from printers' type. On the upper disk is a card printed to correspond with the signs below. A handle connects with a post running down to the type disk, which turns responsive to action on the handle. The edge of the upper disk, about the dial card, is raised and notched opposite the several characters, and the printing is accomplished by putting the handle in one of the notches and pressing down. The entire carriage falls, being hinged on the front horizontal bar, and held up by a spring which returns it from each impression. When the carriage is pushed down, a ratchet in front acts and moves it along over another space. This ratchet is released, when desired, by the hand, and the carriage put at any point on the line. The paper is inserted over a leather-covered roller at the back, and held by a clip of metal, moving forward a line by a turn on the button at the left end. The ink is supplied by small felt rollers held against the line of type on the under disk. Several styles of type are offered. The machine is sold for $10.

A type writer which first received any considerable publicity by its exhibition at the American Institute Fair in New York, in 1884, is the Columbia (Fig. 8). It is

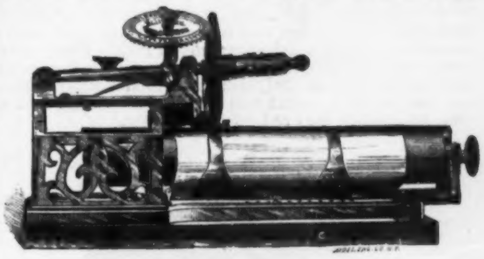


FIG. 8.

the invention of Charles Spiro, of New York. The cut is of the No. 1 style, single case. The base is wood. The apparatus complete weighs about three pounds, is nine inches long, three and a half inches wide, and about seven inches high. In the cut, two disks may be seen. One is vertical and revolves, and the other is horizontal and stationary. The vertical disk has printers' type driven into its periphery, and moves over the rubber-covered cylinder platen below. It is journaled on an axis hinged to a frame at its opposite end. This type wheel is actuated by the fingers twirling the handle on its right side.

Around the face of the horizontal disk are shown the characters employed in printing, and over them a hand moves, connected with and responsive to the action of the type wheel. The hand is stopped by the operator over the sign desired at the impression point, when the type wheel is pressed downward and locked to print, and is returned to its first station by the force of a spring underneath its support. As the wheel is depressed, a ratchet connection with the paper carriage is acted, and the paper passed before another space for an impression. This device is regulated to space for the characters according to their thickness, giving the work more the appearance of common print. Just from under the left edge of the index disk is exposed a key governing the spacing between words; also it serves to release the ratchet connection when the printed line is complete, so that the paper carriage may be returned to the point wished for renewing the printing.

The paper carriage moves in suitable ways, and may be set for margin at either side. Paper is inserted from the back, and held in position by the metal fingers, as shown. When printed, it passes off behind the machine under the ratchet bar. It is moved up regular spaces for successive lines by turning the button at the right end of the cylinder. The ordinary printed line is eight and a half inches. Impressions are direct from the type. Ink is held on a circular pad hanging down at the left side of the type wheel, revolving by motion therefrom, and swerving out of the way when an impression is made, re-inking before another succeeds. The ink pads and type wheels are quickly removable for using other colors of ink or styles of type, ten different faces being offered. A double-case machine is made, having two rows of characters around the dial and corresponding type in the wheel. The single case instrument has forty-four characters, and is sold for $20; and the double case has seventy-two characters, and sells for $30; extra type wheels for No. 1 sell for $1, and for No. 2 for $3 and $4; either number with paper carriage length increased to twelve inches, printing a line of eleven and a half inches, has $5 added to the price. Manifolding is practicable with any style.

The People's type writer is the invention of E. Prouty, of Chicago, who has patented several forms of printing presses, and was first put on sale early in 1885. It is very simple throughout, as a study of the cut (Fig. 9) will show. The base is of cast iron. The bar from

FIG. 9.

side to side at the back supports the printing carriage, which may be seen extending from front to back over the base. This carriage at the front end rests on a post topped by a spring and held in a socket, to which is attached a device working through a series of teeth as the carriage is depressed, and drawing it to successive spaces. The carriage is a groove on its upper side, and in the groove rests a metal bow, having on its upper and lower sides characters for printing. They are electrotyped from a selected job face. This bow at one end is attached to a slide working in the groove, and at the other has a finger piece. A shield stands between the fingers and the type, and holds on its corners a locking peg that fits into holes on the right, opposite the index of characters used mounted on the other side of the groove. In the bottom of the groove at this point lies a piece of cloth saturated with ink, and, when impressions are made, type rest on it. The paper is held over a rubber-covered cylinder platen, the bottom of the printing carriage being perforated at its line of crossing to allow the passage of a letter on the under side of the type bar. The bow is turned as the signs

on either side are needed. The single case machine, with sixty characters, sells for $20; the double case, bow triangular, with ninety characters, sells for $25. The weight is about ten pounds.

About the time of the introduction of the caligraph, when the difficulties in the way of its manufacture were being realized, and there were many persons who had set a higher standard than they thought that machine or the Remington promised ever to reach, occasional mention of the Crandall type writer appeared in short-hand journals. It was easy then, more so than now, even, to excite interest in such a subject, and wide advertisement was had from correspondence alone. This machine is the invention of L. S. Crandall, a native of New York State, who had thought over the subject of type writing for years, and had previously taken out a patent for a complete instrument in 1875. That, however, was abandoned for what seemed good reasons, and another and entirely different model was worked out, for which a patent was awarded about the end of 1881, and which we are now considering.

FIG. 10.

With great hopes, founded on most encouraging inquiries, plans were laid for manufacture, at Boldgett's Mills, New York, and a few machines were built, when fire destroyed the factory and necessitated a start again almost from the beginning. This was deplorable. Notwithstanding, affairs were persevered with, under continued favoring inquiries, and new interest in a measure seemed inspired by the distressing circumstances. As with its predecessors, the display of the few completed instruments was beneficial for the Crandall, since the class it appealed to most directly, and which had manifested the highest curiosity, had grown more critical than ever. There was no hesitation whatever in finding fault, and all comments, wise and otherwise, were duly pondered on profitably, the consequence being that the machine itself was greatly advanced in durability and utility. The manufacture was removed to Syracuse, New York, in charge of the Crandall Type Writer Co., properly organized. From time to time, sales were made, and the improved construction won much praise. Last year it was thought for a while that general sale was feasible, when the standard of execution was set forward a point, and the output was restricted. Now, however, the market is considered open, and the Crandall undertakes to do its part to occupy it. Fig. 10 shows the general aspect of the machine as it stands ready for working, which is easier on a low table, as with other keyed type writers. It weighs fifteen pounds, is fifteen inches in depth, thirteen in breadth, and seven high. The base is cast iron, and the principal working parts steel. There are twenty-eight printing keys for eighty-four characters, two shifts being employed. Each key has its lever, which is in two pieces, or has an extension, all converging toward the back of the machine. The characters are taken from printers' faces, electrotyped, and mounted in rows on a cylinder of wood, exposing fourteen sides. This cylinder is called the type sleeve, is adjustable instantly, and is inserted over a nearly vertical post, supported by a swing above the levers about in the center of the machine. Fig. 11 shows a type sleeve in actual size. Inking is by a ribbon, arranged to work substantially as in other styles of type writers. The paper carriage is shown over the back of the machine, and travels ahead along the line by force of a coiled spring and cord connection, being arranged to stop going either way at any point desired, by either pushing or drawing. The impression is received on a rubber-covered roller. To print, push down a lever by its key, when a comb device from the rear twirls around the type sleeve to present the corresponding letter opposite a space on the paper, and the bottom of the swing is drawn back, throwing forward the top of the type sleeve toward the paper, which is impressed on by the blow. Releasing the key, by sundry springs all connecting parts are returned to their places. The paper carriage moves over a succeeding space at this time, of

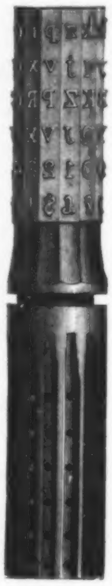


FIG. 11.

course, but by an original attachment the spacing is equal between all letters, thick and thin. Eight inch paper is the limit in width, the longest printed line allowing a half inch margin on each side. Manifolding is practicable. But one style of machine is made, selling for $60. Several different faces of type are employed, and extra type sleeves sell at $3 each.

(*To be continued.*)

BLAST FURNACE PRACTICE.

AT the recent meeting of the American Institute of Mining Engineers a paper was read on "The Irregularities of the Blast Furnace Process, and a Practical Way to avoid Them," by Edward Walsh, Jr., of St. Louis. The author compared the various blast furnaces of note both in England and in America. He stated that the application of the principles of science, especially during the last ten or fifteen years, has, to all intents and purposes, taken away the elements of uncertainty entering into the old process, except, possibly, as to the economic results to be obtained from superheating the blast, the proper cubic capacity of the furnace, and the best internal configuration to be given to it. Little need be said at present about superheated blast, for the best minds of the profession are anxiously watching the conclusions to be reached from actual practice. The economic capacity will be in dispute until the limit of the diameter of the hearth, or the limit of the diameter of the tuyere circle, has been reached. This subject will not be discussed here except incidentally. But with regard to the shape, or "lines," much can be said; for the blast furnace is very defective in this respect, as attested by the variety of forms heretofore and now in use, by the traditions of the practice, and by the literature of the subject.

The contrast between the old Western practice and the modern, as shown in Figs. 1 and 2, is quite marked, and a study of these forms will be extremely interesting. The various forms of English furnaces are also shown in Figs. 3 and 4, and it will be at once seen by inspection that the tendency is to make a flat bosh (Figs. 3 and 4). The author then quoted freely from Mr. Howson's remarks at the September, 1883, meeting of the British Iron and Steel Institute. He said the formation of "scaffolds" and irregularities of working are believed to be due to the interior form of the furnaces, and said that there were 670 blast furnaces in the United States, representing at least 500 different varieties of design. The lowest is 17 ft. high and the tallest 86 ft., the narrowest is 6 ft. at the bosh and the widest is 21 ft. Following this, the author showed the progress in certain American furnaces under the same management exhibiting the different shapes in the Edgar Thomson and other works as they erected new furnaces (Figs. 5 to 18).

Mr. Walsh's remedy for the irregularities consisted of a flat bosh, the top of it being below the upper limit of the zone of fusion, and his analysis of the successful practice in this direction would seem to prove the correctness of his position. He thinks the commencement of "scaffolds" is generally located in the upper portion of the zone of fusion, but they may probably begin just above the zone of complete fusion. When this zone had been properly determined, the portion immediately above it should be arranged to deliver the pasty material regularly and without any possibility of interruption. This he thinks can best be done by placing the bosh entirely and safely within the zone of complete fusion, and by giving the walls immediately above the top of the bosh an upward and inward inclination. He thinks if this is done the liability of adhesions being formed in the bosh will be avoided, and in consequence scaffolding. His ideas are shown practically in Fig. 19, which is his ideal furnace.

He then showed by comparison his design and that of the North Chicago furnace, and again his design compared with the Ormesby and the Clarence, and finally his design and that of the Warwick. The broken lines in each case show the wear on these furnaces (Figs. 20 and 21).

Note how the original lines are cut away in the lower part of this furnace, and that where the original lines intersect the standard, it has not suffered much wear. In the Warwick (Fig. 22), the new design enlarges the hearth to the dimensions actually reached by use. The furnace (Fig. 23) is 37½ ft. high, employs a blast heated to not over 800 deg. Fahr., and yet produces a ton of iron on 70 per cent. fuel, 1,585 lb. of charcoal. It will be seen how nearly the new lines (Fig. 24) coincide with those in practice. Your correspondent has gone somewhat into detail in this paper, because he deems it of great importance, and the discussion which followed sustains this view. Mr. Walsh defended his position well, and showed that there was a constant motion of the stock, and hence little side pressure. At all events, the subject is one well worthy of thought, and a care-

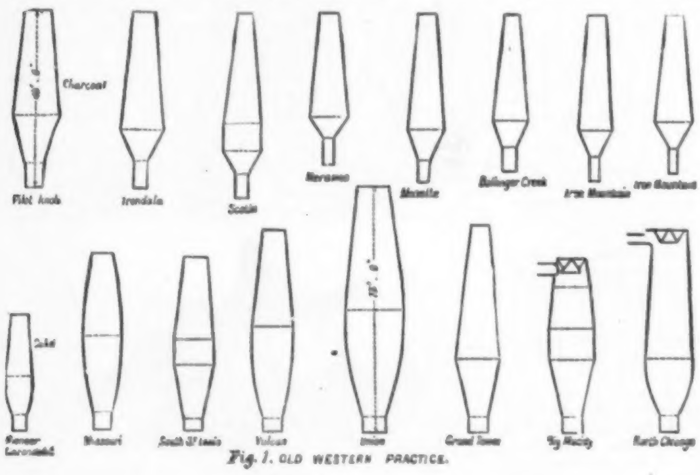


Fig. 1. OLD WESTERN PRACTICE.

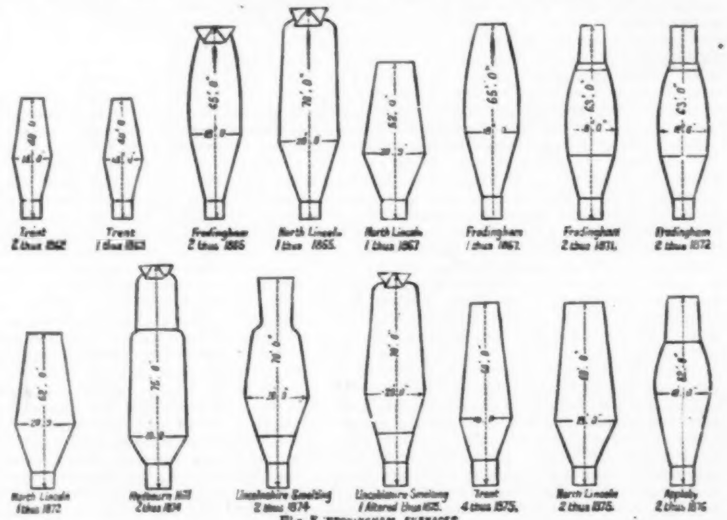


Fig. 3. FRODINGHAM FURNACES.

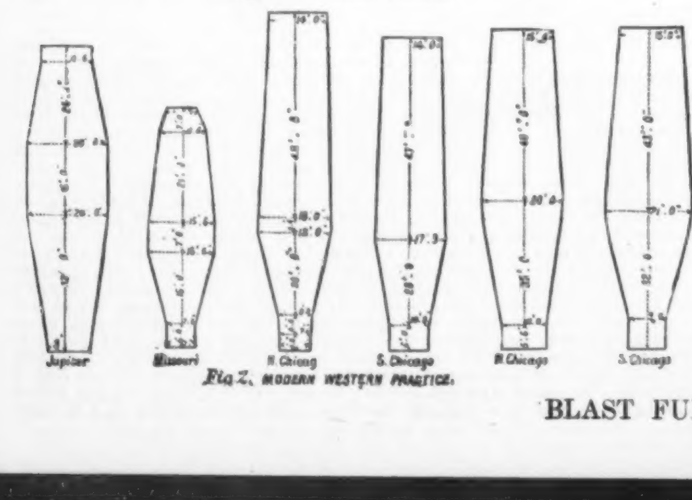


Fig. 2. MODERN WESTERN PRACTICE.

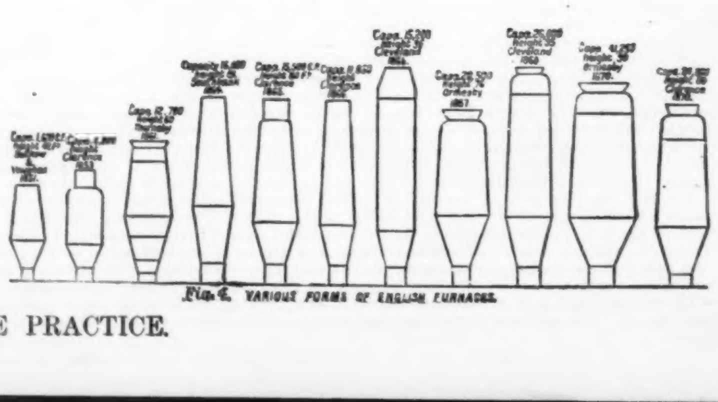
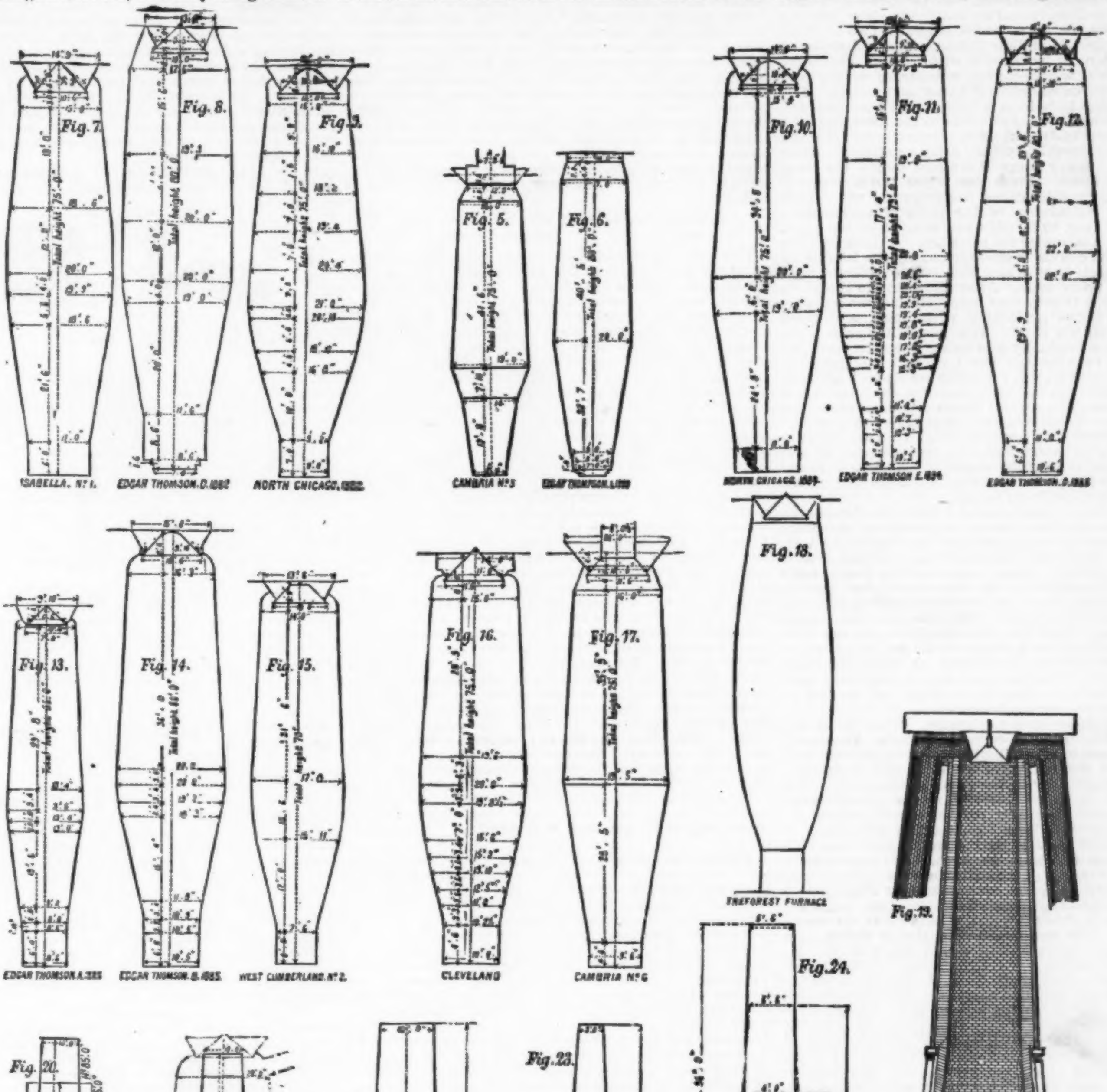


Fig. 4. VARIOUS FORMS OF ENGLISH FURNACES.

BLAST FURNACE PRACTICE.

ful inspection of the diagrams will certainly prove interesting and instructive. It may, however, oe said that there is a coke furnace which presents the following: Capacity, 10,000 cubic feet; diameter of hearth, 10 ft.; height, 6 ft.; diameter of bosh, 16 ft.; neight of bosh to greater diameter, 8 ft.; then in 15 ft. the furnace narrows to 13 ft., and in 56 ft. to 10 feet at the top. The two great objections which Mr. Walsh endeavors to meet are that the fuel may be crushed on the short bosh, and that the cubical capacity of the furnace may be curtailed by the shortness of the bosh. In other words, it is either all bosh, or no bosh about it. Mr. Walsh goes between, evidently being a classical student; and having read that in the middle one goes safest, recommends a flat bosh, and so far his statement, if not a success, is at least a challenge to both extremes.—*Engineering.*



BLAST FURNACE PRACTICE.

INDIGO MANUFACTURE: AN IMPROVED PROCESS.

THE following is a communication to the Society of Dyers and Colorists from Mr. Christopher Rawson, F.C.S., Lecturer on Technical Analysis at the Bradford Technical College.

By far the greatest amount of indigo consumed in this country is obtained from India, and more especially from Bengal, Oude, and Madras. The principal plants cultivated for the manufacture of this important dyeware are the *Indigofera tinctoria, Indigofera anil, Indigofera disperma,* and *Indigofera argentea.* Of these, the *Indigofera tinctoria* is the most abundantly grown. The land is plowed in October or November, and the seed sown toward the end of March or beginning of April. About 30 lb. of seed are required per acre. A light loam is the best kind of soil, and sunshine, with occasional light showers, is most favorable to the growth of the plant. The crop is frequently considerably damaged by long continued rain. The plant grows rapidly, and attains a height of about 3 ft. It is cut for the first time from the middle of June to the beginning of July, varying according to the quality of the soil and the state of the weather. It is important to cut the plants just when mature, indicated by the bursting forth of the flower buds and the expansion of the blossoms. After two months the plants are cut a second time, but the yield of indigo is not so good as that obtained from the first crop.

There are two methods in general use for the treatment of the plants.

I. *From the Fresh Leaves.*—In Bengal the factories usually contain two rows of vats, built of brickwork and lined with stone and cement, the bottom of the one row being nearly upon a level with the top of the other. There are from ten to twenty vats in each series, the area of each vat being about 400 square ft. and the depth about 3 ft. The lower vats, however, are often one-third longer than the upper vats. The cut indigo plants, tied up in bundles, are neatly placed in the upper tanks, care being taken to pack them tightly, since it is important, in order to insure the proper degree of fermentation, that there should be left as little space as possible. The bundles are kept in position, and prevented from floating by wedging stout beams of timber across the tank. Water, which should be clear and of good quality, is then run in so as to completely cover the plants. An active fermentation more or less rapidly commences, lasting on an average from ten to fifteen hours, according to the temperature of the air, the quality of the water, and the ripeness of the plant. A few hours after the immersion of the plant, the condition of the vat must from time to time be carefully examined. If the fermentation is still very rapid, the vat must not be disturbed; but when it becomes more tranquil, it is an indication that the maceration of the plant is complete. Other indications of this point having been attained are the following: (1) When the water, which was at first clean, begins to become muddy and acquire a slight greenish tinge. (2) When bubbles of a greenish color rise to the surface here and there. (3) When toward the edge of the vat some mucilage, or a kind of a grayish scum, commences to be formed. (4) When a very slight purple pellicle is observed on the surface of the liquor, especially near

the corners of the vat. (5) When the liquor begins to exhale a slight, but not disagreeable, odor of herbs. The liquor is now run off from the steeping into the lower or beating vats. If the liquor is of a pale yellow tint, the product obtained from it will be much richer in quality, but not so abundant as if it had a golden yellow color. The average temperature of the liquor at this period is 30° C. From 10 to 18 men enter each vat and beat up the liquor with oars or shovels 4 ft. long, keeping up the agitation from 1½ to 3 hours. The yellow liquor gradually becomes green, and finally separates and precipitates in flakes. It is of importance that this process should be broken off at the right moment, for if it be continued too long, the precipitate formed at first will redissolve and be lost. After the beating process, the liquor is allowed to stand for two or three hours, and as the indigo subsides the supernatant liquid, which must be clear, is withdrawn. The blue, pulpy mass is now collected in a separate vessel, and pumped up into a caldron of water and boiled. The principal object in boiling is to prevent a second fermentation, which would give rise to the formation of a brown resinous body, but at the same time it frees the indigo from a worthless yellow coloring matter. After standing for twenty hours, it is again boiled for from three to four hours. From the boiler the mixture is run on to a large filter called the *dripping vat*, which for a factory containing twelve pairs of preparation vats is 20 ft. long, 10 ft. wide, and 3 ft. deep, having a false bottom 2 ft. under the top edge. A thick woolen cloth or strong canvas is stretched along the bottom of the inner vessel, upon which the indigo collects as a bluish-black pasty mass. After allowing the liquid to drain for about twenty-four hours, the magma is placed into wooden boxes perforated with holes, and lined with strong cotton cloth. The pasty indigo is then submitted to a gradually increasing pressure, until no more liquid runs out at the bottom. The pressure having been withdrawn, the boxes are opened and the blocks of indigo cut up, by means of a knife or brass wire, into pieces of a cubical shape, usually measuring 3 in. each way. These cubes are then taken to the drying house, where they are placed on trellises covered with matting, so as to admit of a free passage of air. Direct sunlight is carefully excluded, and care is taken not to dry the indigo too rapidly. Each fermenting vat yields from 36 to 50 lb. of indigo.

II. *Indigo from Dried Leaves.*—The ripe plant is cut in dry weather an hour or two before sunset, and then dried in the sun on two consecutive days between 9 A.M. and 4 P.M. When dry, the plants are submitted to a process of thrashing, so as to separate the leaves from the stems. The leaves in the course of a few weeks undergo a change in color; their beautiful green tint turning a pale bluish gray. The leaves are now ready for extraction. They are put into a steeping vat with six times their bulk of water, and allowed to macerate for two hours, with continual stirring, till all the floating leaves sink. The fine green liquor is then drawn off into the beating vats without delay, and treated as in the process previously described.

The new process of manufacture, which is in the hands of a company known as the Indigo Company, Limited, claims to effect the complete separation and conversion of the indican present in the indigofera, etc., into indigotin, by the action of ammonia or other alkalies, and by more powerful means of oxidation. Two methods of treatment are described, named respectively the "cold" and "boiling" water process.

I. *The Cold Water Process.*—The indigo plant is steeped in vats with water at its normal temperature, and the same length of time given as is usually allowed in the ordinary process of manufacture. The liquor is then drawn into the lower or beating vats, when the fermentation is either stopped or reduced to an insensible point. The temperature of the liquor is now rapidly raised by means of steam pipes to 96° F., whereby the portion of the glucoside which has escaped decomposition in the fermentation vat is entirely converted and rendered available for the production of indigo blue. Ammonia is added to the liquid in quantities up to 250 lb. of liquor ammonia, sp. gr. 0·880, per 1,000 cubic feet of pressed plant. The amount required to be added varies according to the quality of the plant, the soil on which it is grown, and the temperature of the external air. A solution of nitrate of potash or soda in the proportion of five pounds or more of the salt per 1,000 cubic feet of plant is then added to the vat, and the beating or oxidation process is carried on as rapidly and effectually as it can possibly be done without causing too violent a disturbance in the liquor. This is effected by employing one or more of the following devices:

(*a*) By having beating vats of more than double the ordinary area, so as to expose a greater surface of liquid to the air.

(*b*) By having double the number of vat beaters usually employed.

(*c*) When the liquor is to be beaten by means of mechanical power, only that machinery is employed which causes the greatest exposure of the liquid to the air, and which does not produce too violent a disturbance in the liquor itself.

(*d*) By blowing atmospheric air, or preferably ozonized air, produced by electric discharges from bellows, fans, or air pumps, into the liquor. The temperature of the air blown in may be advantageously raised to that of the vat. The other operations are conducted in a similar manner to those described under the ordinary process of indigo manufacture.

II. *The Boiling Water Process.*—Small shallow vats (2 ft. 6 in. deep) are used for this process. Water is run in and heated to the boiling point, and the indigo plant, in small loose bundles, introduced for a few minutes only. As soon as the scalding is complete, which is known by the liquor attaining a yellowish green color, the solution is rapidly drawn off into the beating vat. The requisite quantity of ammonia is then added, and the liquor treated in the same manner as in the "cold water" process.

In either case, other alkalies may be used in place of ammonia, although the latter is much preferred by the patentee. He finds that ammonia has the property of combining more readily with indican and its derivatives than any other alkalies. Ammonia also yields the best quality of indigo.

The chemistry of the process is rather involved. Indican is a glucoside, and is readily soluble in water. Ammonia is stated to unite with the indican, forming a body which is highly susceptible of oxidation, and which yields a far greater quantity of indigo than indican itself. In the ordinary steeping vat, ammonia is produced by the fermentation of the nitrogenous substances present in the indigo plant, but not in sufficient quantity to combine with and convert the whole of the indican into the readily oxidizable body which afterward yields indigo blue. In the ordinary process of manufacture, therefore, there is always a great loss from a portion of the indican escaping conversion into indigo blue. The ammonia added, as previously described, effects the complete oxidation and decomposition of the indican, thus utilizing the whole of the indigo-producing bodies present in the plant.

The changes which occur during the fermentation of the *Indigofera*, and during the ordinary treatment which the liquid receives in the beating vats, have never been scientifically examined, but, reasoning by analogy, principally from Dr. Schunck's investigations upon the coloring principles of the *Isatis tinctoria* or common woad, it is generally considered that during the steeping process the indican dissolves as a glucoside, and in consequence of the fermentation which ensues is decomposed into indigotin and a peculiar sugar named indiglucin. Schunck expresses the formula of indican and the decomposition it undergoes as follows:

$$\underset{\text{Indican.}}{2C_{26}H_{31}NO_{17}}+4H_2O=\underset{\text{Indigotin.}}{C_{16}H_{10}N_2O_2}+\underset{\text{Indiglucin (sugar).}}{6C_6H_{10}O_6}.$$

The indigotin would then be precipitated, but since ammonia is produced at the same time, it is, by the simultaneous action of the alkali and sugar or other organic matters present in the liquor, reduced and kept in solution, thus forming a true indigo vat, from which the indigo is afterward precipitated by the action of atmospheric oxygen during the beating process. However, if this simple view of the chemical changes which take place be correct, it is difficult to conceive how the addition of ammonia to the beating vat can affect the ultimate yield of indigo. And yet when the two methods are worked side by side with the same quality of plant, and under similar conditions, the "ammonia process" gives an increase of indigo ranging from 50 to 100 per cent. (or even more) above the ordinary system.

I have analyzed a number of samples of indigo manufactured by the "ammonia process," several of which were kindly supplied to me by the Indigo Company, Limited. The indigoes were made in various factories, and naturally varied somewhat regarding the actual percentage of coloring matter present, but they were all of good average quality. Unfortunately, with one exception, I was unable to obtain samples representing the indigo made by the ordinary process at the same factories. Therefore in those cases it is needless to give the actual figures of analysis. However, one case may prove the rule. Two samples of indigo were supplied to me which had been produced at the Belsund factory. In one case the indigo had been made by the ordinary method, and the other manufactured on the following day by the "ammonia" process. The plants treated were of the same quality, the amount put into the steeping vats in each case carefully noted, and the yield of indigo obtained therefrom accurately weighed. The operations were conducted in such a manner as to give every opportunity of allowing the two processes to be strictly compared. The result was an increase of production of 120 per cent. in favor of the "ammonia" process.

The analyses show that although the indigo made by the "ammonia" process contains more mineral matter than that made in the ordinary way, yet it also contains more coloring matter, and its tinctorial value is nearly 10 per cent. higher than the latter. It will also be observed that the "ammonia" indigo contains much less brown and resinous matter. The ash is rather excessive in this and some other samples produced by the "ammonia" process, owing to the heavy rain in the autumn of 1885 causing the water to be muddy, which, on addition of ammonia to the beating vats, precipitated with the indigo. However, in order to avoid this in future, the water will be filtered before running into the beating vats. The analytical results were further confirmed by dyeing woolen yarn with equal weights of the indigoes dissolved in sulphuric acid.

AN IRON MICROPHONE.

THE accompanying figures represent a new form of microphone, into the construction of which nothing but iron and steel enters.

In Fig. 1, three steel or iron spheres rest upon the edges of two iron rails or pieces of steel spring lying parallel at a slight distance apart, and connected with each other through the contact of the spheres. The current enters through one of the rails, traverses the balls, and makes its exit through the other rail, in the direction shown by the arrows. These rails form the electrodes.

The balls are of the size of a pea, and are two or three in number. The details naturally vary according to circumstances. The combination forms a single microphonic element; but we may connect several, as shown in Fig. 2, where the current traverses all the elements. This arrangement gives a more energetic effect than that obtained with a single series. A single ball placed upon the rails would naturally constitute a microphone, but it is better to have several. These metallic microphones are capricious, and difficult of management, and experience has taught me to mistrust a simple metallic contact, which is not always reliable. The action of such contacts often diminishes with time, especially where it concerns flat ones.

The spherical surfaces of the balls, resting upon the sharp edges, present less danger; but the inconvenience is evidently due to the fact that the metallic surfaces in contact wear away under the influence of the current.

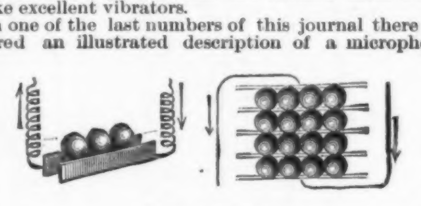
The points of contact in a microphone wear away absolutely in the same way as do the ends of the carbon in arc lamps. The current effects a carriage of the particles.

In a carbon microphone, such a loss seems to be of less consequence than in metallic ones. The construction of these latter, then, requires less care. Carbon contacts easily form a microphone, and the carbon may have any form whatever—that of a rod, points, blocks, or powder.

The same is not the case with metals, which present peculiar characters that must not be lost sight of. The nature and wear of the surface form a part of these, and, moreover, it is evident that metals give a shorter distance of discharge than carbon does, that is to say, they interrupt the current more easily, through their vibrations, than carbon contacts do. It results from this that a vibration that produces no interruption of the current in a carbon microphone will have the contrary effect in a metallic apparatus, and will prevent the latter from operating. This is why, in my first experiments, I tried to reduce or modify the sonorous vibrations so as not to disturb the metallic contacts too much, and with this end in view I employed liquid vibrators.

Prof. Hughes is the first one, to my knowledge, who used a liquid vibrator for the microphone. I remember having seen him immerse a carbon microphone in water. The transmission of words uttered before the surface of the water and transmitted by the microphone to the bottom of the liquid was very clear. I have substituted oil for the water, so that the iron microphone might be preserved in it, and have found that the fluidity of certain oils renders them fit to make excellent vibrators.

In one of the last numbers of this journal there appeared an illustrated description of a microphone



FIGS. 1 AND 2.

transmitter, with metallic contact, of Messrs. Edison and Bergmann, in which a liquid vibrator is combined with metallic points, in order to modify the sonorous vibrations before they reach the metallic contacts. In this apparatus, the liquid does not surround the contacts, but is contained in a box between two diaphragms, to one of which the microphone is attached. I may add that this arrangement was patented in England a few years ago by myself and another person. These two things, that is, the extent of the vibrations and the condition of the surfaces in contact, are the most important considerations in the construction of a metallic microphone, and, in a great measure, determine the form thereof.

Again, it is necessary to know whether or not it is well to use a diaphragm. In England we have reached the conclusion that a Hughes microphone, with a diaphragm, forms an Edison transmitter, whatever be the construction or whatever be the materials used. An instrument without a diaphragm would have little chance of being considered as a Hughes microphone; but, up to the present, no one has been able to produce in court a microphone without any sort of diaphragm, and, consequently, judges have considered all forms of microphones as infringements of the Edison patent.

Prof. S. P. Thompson's microphone, in which the air directly strikes the movable piece, has not as yet been attacked; but this is the sole exception.

Fig. 3 represents one of the microphones whose principle is shown in Fig. 1.

It is contained in a small box, A, surrounded by a thin plate suspended by elastic cords from three brass supports, B C D. These latter are mounted upon a board, E, which is provided with two terminals, *t* and *f*, connected by fine wires with the rails of the microphone in the box, A.

The current traverses the microphone by passing from one terminal to the other.

The elastic cords support the microphone, to which the air has no access, and which consequently cannot get rusty, for the box is hermetically closed. The speaking is done over the box, A.

This form of the apparatus, which has been constructed by Mr. B. Warwick and myself, is objectionable in one respect, since the box, A, and the plate constitute a sort of diaphragm. So we have devised another model, in which the contacts are directly exposed to the sonorous waves, as in Fig. 2.

The speaking is done in a tube, and the vibrations traverse the microphone. This model, however, does not permit of iron being used, since the moisture of the breath would oxidize that metal, unless special precautions were taken; but other metals can be used.

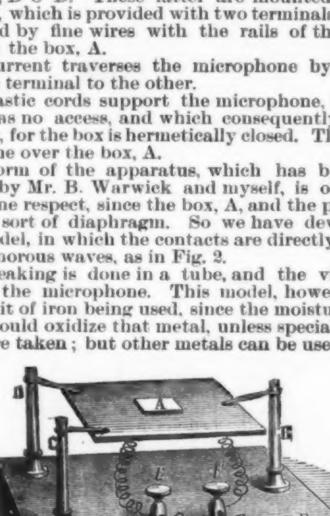


FIG. 3.

Necessarily, the balls should not be held in place, but should move freely over a small extent of the rail, so as to present different surfaces of contact. Finally, instead of balls, cylinders may be employed.—*J. Munro, in La Lumière Électrique.*

SUGGESTION ABOUT CANCELING POSTAGE STAMPS.

To the Editor of the Scientific American:

Referring to an article that appeared in your paper some time since in regard to the want of the Post Office Department of an improved stamp for the purpose of canceling postage stamps so perfectly that it would prevent their being used again, I make this suggestion to your inventive readers. As electricity can be readily obtained, why not connect a flexible wire to a stamp holder, to convey a current through platinum wires to that part of the face of the stamp which does the canceling?

The wire of platinum would be at a "white heat," and every time it touched a stamp it would so brown and bake the paper that it would crumble to pieces if removed from the envelope. I tried it with a heated wire, and it canceled the stamp without injury to the envelope. C. H. ROBERTS.

Troy, N. Y., Oct. 28, 1886.

THE BLACKPOOL ELECTRIC TRAMWAY.

THERE appears to be no doubt that in the future, and in quite a near one, propulsion upon tramways in large cities will be effected by electricity; and it would be superfluous to once again set forth the numerous advantages peculiar to this mode of actuating cars.

The only question is to know what system to give preference to, and as regards this, those at present in operation are giving some valuable information.

Three general systems are now being worked: (1) The accumulator system, applied at Hamburg, and in course of application at Brussels, and which we have recently described; (2) the underground conductor system; and (3) the aerial conductor system, which has

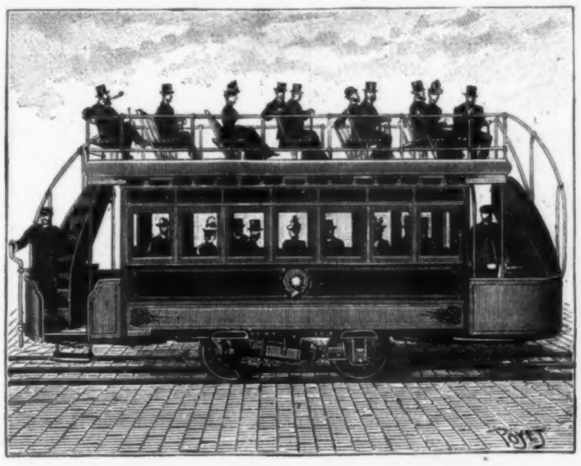


FIG. 1.—ELECTRIC CAR OF BLACKPOOL TRAMWAY.

been applied in a few American cities, and which we shall some day speak of again.

The second system already comprises several varieties, all of which do not offer to the same degree the qualities that are indispensable for rendering the application practical, that is to say, safety for the public, advantageous utilization, and economical operation.

It is unnecessary to say that in all cases where the roadway is not exclusively reserved for the travel of vehicles (and this is the case where tramways properly so called are concerned), the use of two rails as conductors is impossible. It is then necessary to have recourse to an insulated conductor laid between the two rails, which latter serve in common as a return conductor. But the conditions to be fulfilled in the establishment and practical operation of a road thus constituted are numerous and difficult, and are thus summarized by Mr. Holroyd Smith, the inventor of the system which we are about to describe:

A. *Conditions Relative to the Conductors.*—The electrical conductors must be protected, and so arranged that it shall be possible to establish and maintain a permanent and sure contact. The insulation must be sufficient, and easy to clean and renew. It must be easy to inspect and to regularly clean the road, in order to remove such ordinary or accidental dirt as is capable of interfering with the conductors. There must be special arrangements for crossings and bifurcations, in order to avoid short circuits or interruptions.

B. *Conditions Relative to the Sliding Collector.*—There must be arrangements for maintaining a permanent contact, and for avoiding any mechanical or electrical accident in case the conductor should get obstructed.

C. *Conditions Relative to the Motor.*—The motor must be of a peculiar structure, to permit it to withstand the numerous, and sometimes severe, ordeals of service. The actuating of the driving wheels must be as easy and as silent as possible, with slight loss in transmission. There must be electrical and mechanical arrangements to allow the motor to operate equally well in both directions, and be controlled at either end of the car. The mechanism must be simple, in order that the whole may be understood and maneuvered by an ordinary workman. Precautions must be taken against any serious damage in case of an error committed by the conductor.

D. *General Conditions.*—The production at the station must be sufficient, and be regulated. Precautions must be taken against accidental short circuits. There must be no long stoppages in case of accidents.

We can now enter upon a description of the system applied at Blackpool, an experimental trial of which was made near Maillot gate, at Paris, about two months ago.

The Line.—The Blackpool tramway line is about two miles in length. The electrical station is located near the center, this being the most advantageous situation from an electrical point of view. The line happens to be established under extraordinarily unfavorable circumstances, since it runs along the seashore, and in bad weather, although the level of the rails is above that of high tide, the waves sometimes submerge it. In such a case, it is unnecessary to say that operations have to be suspended, the insulated conductor being thus put in communication with the earth. The return is effected through the ordinary rails and the rims of the wheels.

Cars.—The cars are ten in number, and are of various forms. The lightest are summer cars, and are open and capable of seating twenty-six passengers. The largest, which are provided with seats on the roof, accommodate fifty-six persons. It is one of these that is represented in Fig. 1.

The Motor.—The motor is of the Elwell-Parker type, excited in series, and capable of revolving in both directions without a renewal of the brushes. Change of direction is effected by changing the direction of the current in the armature, thus reversing the direction of revolution. The driving axle is actuated by an endless screw that acts upon a helicoidal pinion, reducing, through this sole intermedium, the angular speed of 13 on the shaft of the motor to 1 upon the axle of the driving wheels.

This mode of actuating, which seems as if it ought to absorb an important fraction of the power produced by the electric motor, has, on the contrary, given so satisfactory results that the inventor has the intention of employing it exclusively on all the new cars.

Fig. 2 shows the principal arrangements of the central conductor, of the motor, of the collector, and of the endless-screw driving gear, which constitute the principal parts of the system.

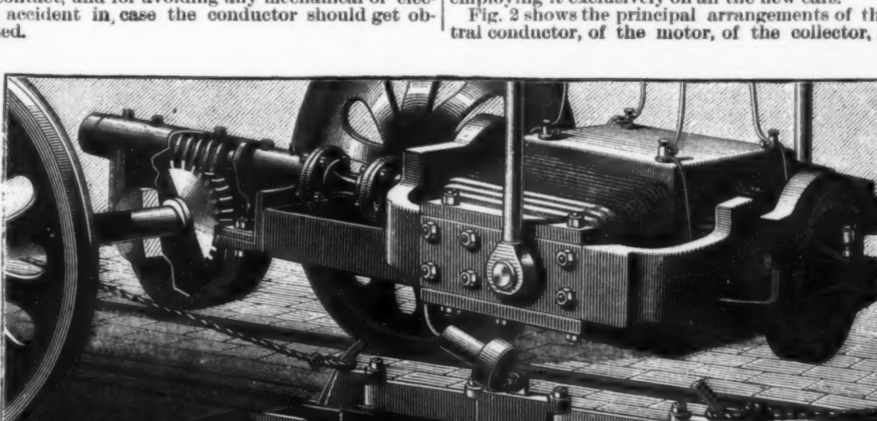


FIG. 2.—ARRANGEMENT OF MOTOR, CONDUCTOR, AND COLLECTOR.

The central conductor lies in a sort of rectangular cast iron trough set into a pavement of creosoted wood and resting upon iron supports placed at certain distances apart. This conductor, which is formed of two strips of copper bent into tubular form and slit in the direction of a generatrix, is held by porcelain insulators fixed to the supports. It is in the space between these two tubes that slides the collector that leads the current to the motor. The longitudinal slit in the pavement above the iron channel is narrower than the interval between the two copper tubes. The object of such an arrangement is to allow stones and other objects to fall to the bottom without being arrested by the conductors. The junctions between the conductors are made by means of brass cylinders that exactly fill the hollow of the tubes. The current collector consists of three parts, viz., of an insulated strip of metal to which is attached a cross piece that serves to guide it in the slit and prevent it from wedging. The current is taken up by two curved pieces of bronze, each of which embraces a part of the two conducting tubes and exerts a permanent contact. The central piece is carefully insulated, and leads the current to the motor through a flexible wire attached to the piece just mentioned by a peculiar sleeve having the following functions: When the front portion of the guide meets but a slight obstacle, it pushes it away and continues its travel; but when the obstacle (such, for example, as a large iron spike driven in by malicious persons, as was done at the first experiments at Blackpool) is resistant, the traction rope of the collector becomes disengaged, as does also the sleeve that affords an electric communication between the motor and collector. This latter stops, and the car continues its travel by virtue of the velocity that it has acquired, and stops a little further along; so all breakage is thus avoided. It is only necessary to remove the obstacle, hook on the rope again, and fix the electric sleeve, in order that everything shall be again in running order.

Starting Gear.—The starting and stopping of the motor are controlled by a commutator which has the effect of introducing into the circuit variable and gradually increasing or decreasing resistances. There are two maneuvering boxes placed at the two ends of the car, but only one of these can be used at a time, since the current enters neither until a key has first been inserted. Each car is provided with but one of these keys. It is an application of the block system, known in England as the "staff system."

The central station is provided with two dynamos separately excited by two other machines of smaller size. Each of the generating machines is capable of producing 300 volts and 180 amperes at a maximum. In practice, the effective potential varies between 220 volts near the station and 170 at one of the extremities. The difference is due to the imperfect insulation of the line.

Such are the principal features connected with the operation of the Blackpool electrical tramway. The sole objection that can be urged against the system resides in the cost of first laying the central conductor, and in the losses that it occasions. Is it better to invest this capital in a special road, or an equivalent capital in accumulator? Something may be said for and against both systems, and it will be interesting to keep track of the applications made at Hamburg and Blackpool of each. They will afford some useful information upon the question, and will probably give an economic solution upon which will depend the practical extension of that system which is found to be the more advantageous.—*La Nature.*

THE HARCOURT COLOR TESTS.

By H. LEICESTER GRÉVILLE, F.I.C.

IT is probable that the majority of the readers of the *Journal* are acquainted with the Harcourt color tests; but a brief description of the apparatus may be a suitable prelude to recording my own observations in the use of the test, and to describing some slight modifications which I have found useful in practice. The following diagram, Fig. 1, shows the regular apparatus

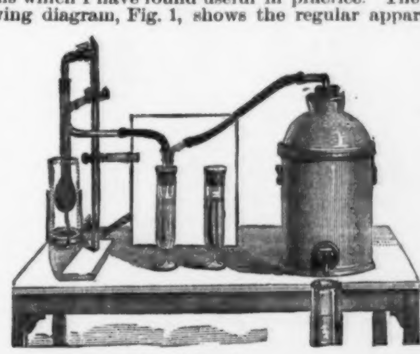


FIG. 1.

(a copy of that given in the instructions for use issued by Messrs. Alex. Wright & Co., of Westminster).

The test for sulphur compounds in which the lamp is used is founded on the fact that when gas containing carbon disulphide vapor is passed through heated platinized pumice, the sulphur of the carbon disulphide is converted into sulphureted hydrogen. Expressed as a chemical equation, the simplest explanation of the reaction is that of a mutual decomposition of carbon disulphide and water vapor, as follows:

$$CS_2 + 2\,H_2O = 2\,H_2S + CO_2.$$

The sulphureted hydrogen so formed in the use of the Harcourt lamp is passed into a measured quantity of a solution of lead so prepared that, in place of sulphide of lead precipitating, it remains dissolved in the liquid, communicating a brown tint proportionate to the amount of sulphureted hydrogen present. The color is compared with a standard color in a tube placed side by side with the tube containing the lead solution. By passing gas from the lamp into the lead solution until the tint is the same as that of the comparison standard, and measuring the volume of gas necessary for the purpose, we are enabled to ascertain the pro-

portion of sulphur as carbon disulphide present. This measurement of the volume of gas is effected by drawing the gas through the lead solution by running water from an aspirator, and measuring the volume of the water by means of the graduated measures—the smaller holding $\frac{1}{200}$ and the larger $\frac{1}{20}$ of a cubic foot. By reference to a table, the amount of "sulphur" is then found, to which is added from 7 to 8 grains, as sulphur present in other forms than carbon disulphide, and therefore not indicated by the lamp. Sulphureted hydrogen in gas is estimated by means of the color standard by drawing the gas directly into the lead solution, without the use of the lamp; while carbonic acid is estimated by the use of a standard containing a known quantity of barium carbonate, and drawing the gas through a solution of barium hydrate until an equal degree of opacity is reached. Reference to a special table then gives the amount of carbonic acid present in the gas.

With regard to my own experiences in the use of the Harcourt tests, I will commence with the subject of heat. On this question my opinion is that a lamp comes more quickly into working order, and affords generally more reliable tests, where the heat is greater than that defined in the printed instructions as "a blue non-luminous ring" of flame. The temperature we generally use is reached by turning up the gas until a distinctly luminous ring of flame is obtained when the small clay pieces on the top of the chimney are in position. Then, as to the time to elapse before taking a test, the instructions state "a testing may be made five minutes after the burner is lit, except when the apparatus is first used, when the gas should be allowed to flow through the bulb for a quarter of an hour or a little longer." My experience of this has been (1) that it is advisable to allow a new lamp to be alight a considerable time before employing it for actual testing; and (2) that although a lamp, after the first time of using, will give a test five minutes after being lit, it will only give a reliable test where the sulphur in the gas being tested is in about the same proportion as in the gas upon which the lamp was last employed. I may here mention that in starting a new lamp a correct test is sooner obtained with gas containing a high proportion of sulphur than where the sulphur is small in quantity. Out of many experiments upon this branch of the subject, I will quote the following: Two new lamps, A and B, were started at the same time, A upon gas containing 18 grains of sulphur per 100 cubic feet, and B on gas containing only 9 grains. A gave a correct result in 1½ hours, while B was 20 hours before it gave a really correct return.

In order to illustrate the effect of transferring a lamp on to gas containing a markedly different quantity of sulphur to that upon which it had previously been used, the following experiments may be quoted: A lamp which was giving a correct result on gas containing 36 grains of sulphur per 100 cubic feet was transferred to gas containing 19 grains. After being on the 19 grain gas for five minutes, the sulphur indicated

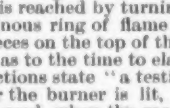


FIG. 2.

was 26·2 grains; after 15 minutes, 26·2 grains; after 80 minutes, 21·3 grains; and after 90 minutes, 19·5 grains. So that 1½ hours had to elapse before a correct test was obtained. In another case a lamp was taken from 22 grain gas and put on to gas containing only 8 grains, with the result that after one hour's interval it indicated 10·8 grains, and after two hours' interval 9·5 grains. The lamp was then turned out; but the experiment clearly shows that upward of two hours was here necessary to get a correct test. In fact, where a lamp is changed on to gas of different composition as regards the proportion of sulphur present, the interval which elapses before a correct test is obtained increases with the difference in the amount of sulphur in the two gases. The due appreciation of this fact is most important, and a knowledge of it has explained many anomalous tests made at an early period of my connection with the Commercial Gas Company, and when the conditions of accuracy were less understood. We now have a separate lamp on each purifier to be tested, instead of transferring a single lamp from one to the other; and by this means, and the observance of general conditions dictated by experience, the tests are rapid and reliable. Of these other conditions, temperature is entitled to the first place; while a proper rate of flow of gas through the lamps, and the maintenance of the platinized pumice in an active condition (by periodically removing any excess of carbon deposit), are also essential.

Treating these three conditions categorically, I have already stated the temperature which I consider best suited for efficient working. It may, however, be useful to show the effect produced by modifications of temperature; and I will therefore quote a few experiments bearing on the subject: Flame normal; grains of sulphur, 16. The flame was now turned up so as to be as high as possible without actually smoking, when the following consecutive tests were obtained, extending over a period of two hours: 27·8, 25·5, 23·7, 23·1, 21·3, 20·9, 19·2, and 18·9 grains. The flame was then turned down to its normal height, and gave 16·1 grains after the lapse of five minutes. In another experiment a lamp was giving 15·3 grains of sulphur with the normal flame; the referees' test on the same gas being 15·6 grains. When the flame was turned down to a "blue non-luminous ring," 12 grains was obtained. I need not quote any further experiments to show that temperature is an important factor in obtaining correct results. At the same time, those accustomed to the use of the test have no difficulty in adjusting the lamp to a proper temperature, judging simply by the appearance of the flame.

The experiments next to be described were made in connection with the effect of velocity on the test. The normal rate is obtained when the passage of gas through the lamp is such as to give a flame about 1 inch high when the jet is lighted, and when during the use of the test the tap of the aspirator is turned on so as to give a slender stream which any check on the tap would break up into a succession of drops. I find this corresponds to a mean rate of about 10 measures per minute. The following experiments illustrate the bearing of this part of the subject:

Time occupied in test. Min.	Sec.	Number of measures.	Grains of sulphur per 100 cubic feet.	Remarks.
1	28	15·0	40·3	Quick.
1	38	13·0	45·5	Normal.
1	12	14·0	42·7	Fast.
1	26	13·0	45·5	Normal.
2	40	10·0	57·0	Slow.
1	0	14·0	42·7	Fast.
2	30	10·5	54·7	Slow.
0	53	14·0	42·7	Fast.
1	30	13·0	45·5	Normal.
2	8	11 5	50·5	Slow.
1	25	12·5	47·1	Normal.

Mean normal time. 10 measures in 62 seconds; mean sulphur, 47·2 grains.
Mean result slow.. 10 " 136 " " 54·0 "
Mean result fast... 10 " 49 " " 42·1 "

In another series of experiments the sulphur indicated was as follows, as a mean of a number of tests:

Normal rate..... 21·5 grains per 100 cubic feet.
Slow.......... ... 23·7 " " "
Fast .... 18·0 " " "

With regard to the maintenance of the platinized pumice in an efficient condition, our custom since the year 1881 has been to aerate the lamps at intervals of about a month, by turning up the flame to considerably more than its usual height, and drawing a slow current of air through. About 0·1 cubic foot generally effects the desired result of burning off the deposited carbon. In addition to this, it is customary whenever a breakage occurs to thoroughly ignite the pumice for some time in a platinum crucible before using it to charge a fresh bulb. In order to illustrate the effect of aerating a lamp which has been in use for some time, the following experiments, made some years back, may be quoted: A lamp showing 12 grains of sulphur on gas which was giving 18 grains by the referees' test had 0·1 cubic foot of air drawn through, and was set to work. After an hour's interval, a test gave 19·2 grains of sulphur; and after a further period of 20 minutes, 18·3 grains—a practically correct result—was obtained. Another lamp, showing 12 grains on a 16·5 grain gas, was treated in a similar way; and, having been set to work, gave a correct result after the lapse of between one and two hours. An old lamp which has been used for some considerable period without aerating has been found to contain as much as 6·1 grains of deposited carbon; and it is obvious how seriously this would interfere with the proper action of the pumice.

In using the Harcourt test for sulphureted hydrogen and carbonic acid, there are also one or two little details conducing to correct results which I may mention. In any case, where the test cannot be taken directly off a leading main—and this is frequently inconvenient—the pipe used for conveying the gas from the main to the testing place should be as short as possible, should be of good diameter, and should be preferably of lead or composition metal. Before commencing, the gas should be allowed to "blow away" for a short time; and subsequently, when taking the test, I prefer to use a small glass tube like that shown in Fig. 2. The gas is connected to one end of the straight tube; the other end communicating with the outside air by a piece of rubber tubing. The inlet to the test glass containing the lead or baryta solution is connected by about an inch of rubber tubing to the end of the bent portion of the glass tube, and the test then taken. The object of this is to take the test always directly off an active current of gas. Where this is not done, my experience has shown that there is a tendency to obtain unduly low results, arising probably from a partial condensation of moisture, laden with sulphureted hydrogen and carbonic acid, in the pipe, when the velocity of the gas is not sufficient to prevent or mitigate such an effect. Contrary to the instructions issued with the test, it is also our practice to make carbonic acid tests directly on the gas, without the intervention of a small oxide vessel for the removal of the sulphureted hydrogen. It was found that the use of a moist porous mass such as was presented by the oxide purifier tended to absorb and retain a portion of the entering carbonic acid for a considerable time after being put on; and, on the other hand, that a clean oxide purifier, when first put on gas free from carbonic acid, showed distinct indications of carbonic acid at the outlet for about one hour. In order to avoid the possibility of errors of this kind, we pass the gas to be tested directly into the solution of barium hydrate. As the contents of the tube are thrown away after use, and as there is always a considerably larger quantity of barium hydrate present than is necessary to combine with both the carbonic acid and the sulphureted hydrogen in the volume of gas used for testing, the presence of the latter impurity does not affect the result.

In conclusion, I may describe some slight modifications in the construction of the apparatus used in the Harcourt tests which I have devised, with the effect of making the apparatus more portable and convenient. The lamp is shown in Fig. 3, where B is the bulb (supported by the arm and screw, K) containing the platinized pumice; C, the Argand burner; F, a solid metal stand; G, the gas inlet; and D and E, the taps—one to control the flow of gas to the burner, and the other to the bulb. D is a three-way tap made by drilling a small hole in the side of the tap right through to the center of the plug. While the gas supplying the burner is regulated by E, the tap, D, may be used either for controlling the gas to the bulb, or by being turned in a particular direction the gas supply is cut off and the bulb placed in connection with the air, so that by means of an aspirator air can be drawn through the pumice for the purpose of burning off any carbon deposit. The dimensions of the lamp are: Base, 3½ inches; extreme height, 8½ inches. The ordinary form of lamp stands about 18 inches high, with a base of about 3 by 5 inches. The top of the bulb is, of course, originally open; A representing where the tube has been sealed after the introduction of the pumice.

Instead of employing two measures—a large and a small one—and an aspirator, I use the glass vessel shown in Fig 4, in which measures and aspirator are combined. The water is run out by the tap into any vessel handy (an ordinary jug answering admirably); and the measures of gas used are read off direct. The upper part of the vessel is small in diameter, while the lower part is considerably larger; the object being to insure the greatest accuracy in reading where the volume of gas is smallest. The vessel stands about 27 inches high, with a base of a little more than 4 inches, and has a total capacity available for measurement of 1·20th of a cubic foot. Where extra portability is desirable, the vessel is made in two parts; the upper and narrower portion fitting into the lower and larger part by a ground-glass joint. The apparatus shown in Fig. 5 is also useful in judging of the respective intensities

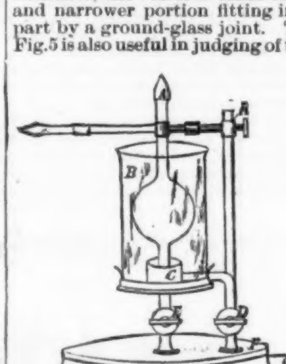


FIG. 3.

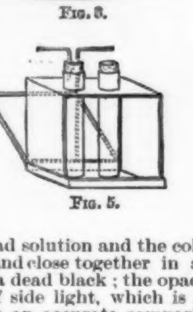


FIG. 5.

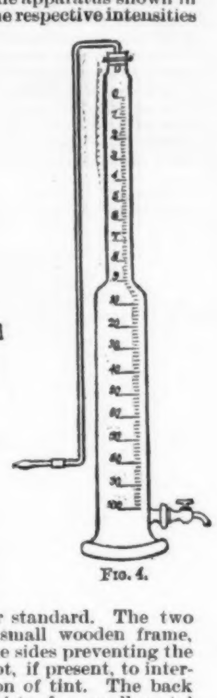


FIG. 4.

of the lead solution and the color standard. The two tubes stand close together in a small wooden frame, painted a dead black; the opaque sides preventing the effects of side light, which is apt, if present, to interfere with an accurate comparison of tint. The back is hinged at the bottom, and consists of a small metal frame fitted with a piece of thin opal glass. When inclined, the light reflected from the white surface enables the comparison tints to be clearly discriminated; and in different conditions of light the back may be closed up, and the tints judged by looking through the test tubes, with the diffused white semi-transparent screen behind.

The whole apparatus—lamp, measure aspirator, tubes, bottles for lead sirup and baryta—packs into a box 20 in. by 13 in. by 10 in., so that it is easily carried about; and I have no doubt, with a full knowledge of the conditions necessary to insure accuracy, a portable form of the Harcourt test that could be taken from place to place would be found a useful and reliable means for testing the condition of the gas in country works. From long experience in the use of the Harcourt tests, I can confidently recommend them as a good practical guide to gas purification. With care, results of sulphur compounds can be obtained within a grain or two of the results of the referees' test; and for carbonic acid and sulphureted hydrogen, the results, although not strictly accurate, are sufficiently correct to give an excellent guide as to the amount of work done by purifiers and scrubbers. The tests also have the great advantage of simplicity, which renders them capable of employment by an intelligent workingman. —*Journal of Gas Lighting.*

THE PRESSURE AND COMPOSITION OF NATURAL GAS.

By Dr. H. M. CHANCE.

IN a paper discussing the "Anticlinal Theory" of Natural Gas,* I have already shown that the pressure under which gas exists beneath the surface in Western Pennsylvania must be limited by the depth of the gas-producing stratum; it must, in other words, be less than the weight of the overlying rocks, which may be taken at one pound per square inch for every foot in depth. This determines the absolute maximum limit for any considerable area of gas-producing rock.

It is, perhaps, possible that the pressure is also limited by the hydrostatic head. We may distinguish two entirely independent hydrostatic pressures which might limit the gas pressure.

1. *Direct pressure* from stream level at the surface above the gas rock, acting through extremely narrow crevices, and thus sealing the gas within its porous sand rock reservoirs. When the gas pressure exceeds this water pressure, the gas must blow off. After the pressure is sufficiently reduced, the water might again seal up the vents. The gas pressure, if so limited, could not exceed $\frac{44}{100}$ pound for each foot in depth of gas sand below surface water level. Thus for 1,500 ft. below water level, the gas pressure limit would be about 650 pounds per square inch, or somewhat less than half the ultimate maximum as limited by rock pressure (weight).

2. *Hydrostatic pressure* acting through each rock from its outcrop at water level in the northern part of Pennsylvania or Southern New York. If we could admit the possibility of such perfect continuity of porosity, or open crevices, or both, as would permit the pressure to be transmitted through eighty or one hundred miles of rock underground from the water level outcrop of the first oil sand near Titusville on Oil Creek, and below Tidioute on the Allegheny River, at an elevation above tide of about 1,100 ft., through and down the slope of the rock to Pittsburg, where this rock lies about 800 ft. *below* tide, then the maximum gas pressure possible would be limited by this difference in elevation.

* Read before the Bethlehem (1886) meeting of the American Institute of Mining Engineers.

The non-porous character of large areas of the rock, the clay luting of the rock joints (cleavage joints), render such an hypothesis improbable, but we have much stronger negative evidence in the salt water wells, many of which, when first struck, flow largely, but after a time, as the gas pressure (from dissolved gas) diminishes, they cease flowing, and in many cases the brine does not rise more than half way to the surface. If the hypothesis of open crevices or continuity of porosity were true, these wells should yield true artesian flows of constant volume.

The hypothesis of direct pressure from the surface is partly disproved by the experience of drillers throughout the oil region, that fresh water is found only to a certain depth—usually 300 to 500 ft.—and that below this, and until salt water is struck—commonly at 800 to 1,400 ft. in the oil regions—the slates and shales passed through are *extremely dry*. This dryness of the underground is not peculiar to the oil regions. In many mining districts the rocks at great depth are exceedingly dry, no water being met after passing below the limit to which the surface water penetrates. In some of our deep anthracite coal mines, and in deep coal mines in other countries, the absence of moisture is such that much inconvenience is experienced from the accumulation of large quantities of exceedingly dry dust.

This fact, that surface water finds its way down to only a limited depth, is sufficient proof that nearly all the cleavage joints and fissures are filled with a practically water-tight clay luting, and it is to this fact that we must attribute the possibility of the existence of large quantities of gas at great pressure. Without such a filling in of the cleavage joints and fissures, such accumulations would evidently be impossible.

Hence these hypotheses both seem to me improbable, and while they would, if true, establish pressure limits very nearly equal to the observed maximum pressures, I believe that this is merely a coincidence brought about in the following way:

We have no records of the gas pressure first shown by the larger wells. The recorded pressures have nearly all been observed after the gas had been blowing off for some weeks, months, or even years, and the pressure then shown by a gauge is evidently no measure of the pressure under which the gas exists in the rock, for the gas soon becomes exhausted from the immediate vicinity of the well, which then draws its supply from a considerable distance, and perhaps through bands of rock of such texture (and, perhaps, even through the clay filling of crevices) that the pressure shown at the well may be only a fraction of the actual pressure.

Hence, while recorded pressures range from about 600 down to 200 pounds per square inch, we have every reason to believe that the actual pressures are perhaps from 500 to 1,000 pounds per square inch, or even in some cases much greater, but must still be less than the maximum as limited by depth. In the paper above mentioned I have shown that this maximum is very much less than the pressure necessary to effect liquefaction, and that we must, therefore, abandon the supposition that the gas exists as a liquid.

One of the most interesting phenomena recently observed in natural gas is its variability. The analyses of Prof. Sadtler,* made some nine years ago, told us that gas from wells located in districts not connected with each other was similar in composition, but that the percentages of the different gases present varied widely. We were, however, not prepared for the discovery that gas from wells in the same "pool" and that from the same well was subject to daily and even hourly variations in composition. When it was found that the calorific value of the fuel was subject to change from time to time, as shown by variations in temperature of the furnaces, and in the steam pressure of boilers under which it was burned, this was at first supposed to be due to differences in pressure, that is, in the quantity of gas delivered to the burners in the fire box. Automatic pressure regulators were introduced, and the producing companies perfected a system by which the pressures were maintained at a nearly constant figure, yet the same variations were observed. The chemists then began to examine the gas, and soon found that it was extremely variable in composition.

As the law of diffusion of gases should effect a thorough mixing of the gases throughout the limits of any gas pool or area of porous rock, we should naturally expect the gas from each such pool to be of uniform composition. Those who uphold the hypothesis of continuous manufacture underground quote this variation in composition as one of the strongest arguments in support of the theory, and as yet the geologists familiar with the phenomena of natural gas, who, almost without exception, have discarded this theory as untrue, have not furnished any explanation of this phenomenon. Two of our most noted scientists versed in the chemistry and geology of natural gas, and disbelieving any theory of continuous production (*pari passu* with consumption), have been disposed to explain this variability by asserting that the law of diffusion may become inoperative in gases under great pressure. As the diffusion of gases results from molecular activity, and as this cannot be destroyed or suppressed by pressure, and as it has never been shown that any of the laws of matter may be annihilated, this assertion appears to me to be entirely without support.

It seems to me entirely possible to account for the phenomena without doing violence to any natural law, and to explain how almost any and every possible variation in the composition of natural gas may, if indeed it must not, occur in the gas as yielded by the wells, while the gas throughout the porous area is of uniform composition. The first four of the following analyses were made from gas taken from the same well at different times. The remaining analyses are of wells in different districts.

The first four analyses show marked variations in hydrogen and ethane. In the gas from the well near Greensburg, from which the Cambria Iron Company is to get its supply, Mr. John Fulton informs me that nitrogen is contained in considerable quantity, and that it is subject to marked and rapid variations.

All rocks are traversed by cleavage joints and fissures. They may be seen in every quarry, in every railroad cut, tunnel, and mine. The rocks of western Pennsylvania are no exception, but the fact that gas exists under great pressure in the porous rocks is sufficient

* Report L, Pennsylvania Geological Survey.

	1	2	3	4	5	6	7	8	9	10
Carbonic acid, CO_2	0·80	0·60	.....	0·40	0·34	0·35	0·66	2·28	.....	0·30
Carbonic oxide, CO	1·00	0·80	0·58	0·40	trace	0·26	trace	....	1·00	0·60
Hydrogen, H ...	20·02	26·16	29·03	35·92	6·10	4·79	13·50	22·50	9·64	14·45
Marsh gas, CH_4..	72·18	65·25	60·70	49·58	75·44	89·65	80·11	60·37	57·85	75·16
Ethane, C_2H_6...	3·60	5·50	7·92	12·30	18·12	4·39	5·72	6·80	5·20	4·80
Propane, C_3H_8...	....	.....	.....	.....	trace	trace	.....	.....	.....	.....
Nitrogen, N ..	.....	.....	.....	.....	.....	....	.....	7·32	23·41	2·89
Oxygen, O.....	1·10	0·80	0·78	0·80	.....	.....	.....	0·83	2·10	1·20
Illuminating hydrocarbons.	0·70	0·80	0·98	0·60	.....	0·56	.....	...	0·80	0·60
Ratio, C to H (weight)......	2·72	2·50	2·64	2·50	3·08	3·00	2·88	2·70	2·91	2·84

1, 2, 3, 4. From well supplying Edgar Thomson Steel Works, by S. A. Ford.
5. Burns well, Butler Co., Pa., by Sadtler.
6. Luckburg well, Armstrong Co., Pa., by Sadtler.
7. Harvey well, Butler Co., Pa., by Sadtler.
8. Cherry Tree well, Indiana Co., Pa., by Sadtler. Small flow through fresh water.
9, 10. Two wells near East Liberty, Allegheny Co., Pa., by S. A. Ford.

evidence that these cleavage joints are sealed with a luting of clay and perhaps calcareous material from percolating water, and the fact that the waters do not now percolate from the surface to a greater depth than 300 to 500 ft. is evidence that these narrow crevices are impervious below that depth. The word crevice or fissure is not exactly applicable to many of these openings, which are merely joints or cleavage planes, and in a few cases only do they have a width entitling them to be termed crevices or fissures.

If these joints in the rocks above the gas sands are luted with clay or calcareous material, then we have every reason to believe that the cleavage joints of the gas rock itself are also partially closed by similar material, and we may, therefore, conclude that every gas area is divided into many subdivisions by diaphragms of clay or calcareous material, through which the gas must diffuse in passing to the well. As the rate of diffusion of gases through porous diaphragms is inversely as the square root of their densities, the gases will diffuse in ratios proportional to the following figures:

		Density.	Rate of Diffusion.
Hydrogen,	H........................	1·	1·
Marsh gas,	CH_4..........................	7·985	[illegible]
Ethane,	C_2H_6..........................	14·97	[illegible]
Nitrogen,	N..........................	14·01	[illegible]

If the diffusion is from an inclosed area, the hydrogen percentage will be largely increased, and the percentages of the other gases decreased. If the diffusion is through a plane along which a current of gas is constantly flowing to find its way by a circuitous route to the well, the diffused gas will contain a still larger percentage of hydrogen, and nearly equal percentages of marsh gas, ethane, and nitrogen. If the diaphragm of clay or calcareous material permits transfusion as well as diffusion, we will have still different percentages.

Again, the gas dissolved and held by salt water contains less hydrogen, nitrogen, and marsh gas, and more ethane, than the free gas. Gas given off from the salt water as the pressure diminishes will, therefore, constitute another variety. If this gas diffuses through a diaphragm on its way to the well, the diffused gas will have a composition dissimilar to any of the mixtures already described, being lower in nitrogen. If this gas flows past a diaphragm while diffusing through it, the diffused gas will contain nearly all the hydrogen, nitrogen, and ethane, and the gas flowing past and around the diaphragm will consist almost entirely of marsh gas.

Hence we have the following varieties:

1. Normal mixture of gas.
2. Gas diffused through diaphragm.
3. Gas left behind diaphragm.
4. Gas diffused through diaphragm while flowing past it.
5. Gas flowing past diaphragm, not diffused.
6. Gas from salt water.
7. Gas from salt water, diffused through diaphragm.
8. Gas from salt water, left behind diaphragm.
9. Gas from salt water, diffused while flowing past diaphragm.
10. Gas from salt water, flowing past diaphragm not diffused.

And, in addition to these varieties, we may have an infinite number of minor variations resulting from the combined action of diffusion and varying rates of transfusion, and from mixtures of these variations with the normal gas mixture we can readily conceive a well so located with reference to a salt water area and to a number of cleavage joint diaphragms that the mixture of gases flowing into it from different directions would be subject to such constant changes that uniformity of composition, even for short periods, would be exceptional and variability the rule.

The solubility of these gases in salt water is not accurately known. The following coefficients of solubility (by volume) in fresh water for a temperature of 20° C. (68° F.) were calculated from the formulæ given by Roscoe and Schorlemmer.*

H	Hydrogen.......	0·01930	1·93 per cent.
CH_4	Marsh gas.......	0·03449	3·45 "
C_2H_6	Ethane.......	0·049	4·90 "
N	Nitrogen.......	0·18	1·80 "

By *Dalton's law of partial pressures* the composition of the dissolved gas is found by multiplying the percentage of each gas by its coefficient of solubility, and dividing each product by the sum of all the products, the results showing the percentage of each gas in the mixture.

The influence of unequal pressures underground caused by the unequal action of several wells drawing gas from the same rock, and the movements of salt water through the rock, will sufficiently account for varying flows of gas toward any one well from different directions. Under such conditions, it is evident that more abrupt changes in composition would occur than in the case of a single well drawing gas from a pool in which water movement could not occur, for in this case the gas flowing toward the well from each direction would maintain a constant ratio to the total flow, and the resulting mixture in the well would remain more nearly constant in composition, except as the mixture coming from any one direction might become exhausted (or slowly change by diffusion) and be replaced by the gas left behind a diaphragm, through which the first mixture had diffused.—*Proc. Eng. Club, May*, 1886.

* Organic Chemistry, vols. i. and iii., pt. 1.

ON THE DETERMINATION OF ALUMINUM IN PRESENCE OF LARGE PROPORTIONS OF IRON.

By ROBERT T. THOMSON.

HAVING lately had occasion to test for and determine a minute proportion of aluminum in presence of a large proportion of iron, I was led to try the capabilities of the two best-known methods, namely, by boiling with a large excess of caustic soda or potash and subsequent precipitation in the filtrate from the peroxide of iron, and by direct precipitation with thiosulphate of sodium. In the latter case only about 90 per cent. of the total aluminum present was obtained, when working on a solution containing 100 parts of iron to 1 part of aluminum. But the failure of the caustic alkali method was more striking, as not a trace of alumina could be detected in the soda filtrate. The solution operated upon contained 2 grms. of iron and 0·02 grm. of aluminum. It was nearly neutralized, and slowly added to a quantity of caustic soda solution heated to boiling in a nickel basin. The mixture was thoroughly boiled, filtered, and tested for alumina, with a negative result, as already stated. The excess of caustic soda used was more than 10 grms. Both of these processes had to be rejected, but I at last hit upon the following method, which gives excellent results:

The iron, if in the ferric state, is first reduced to the ferrous condition by passing a current of sulphurous acid through the solution. The excess of sulphurous acid is boiled off, the mixture cooled, and at least as much phosphoric acid, or phosphate of ammonium or sodium, added as will be equivalent to the alumina present. It is advisable to use a large excess of phosphoric acid, as the alumina may not be completely precipitated if it has not at least its own equivalent of the former. One drawback to the unlimited use of phosphoric acid is that if manganese is present it will be thrown down; but if the quantity of the former is limited, the latter will remain in solution. Where manganese is present in quantity, it is advisable to employ the alternative method of precipitation to be described further on. Ammonia is now added until a faint permanent cloudiness is formed; then excess of ammonium acetate, which throws down the alumina as phosphate. The precipitate always contains some ferric phosphate, which forms from any traces of ferric iron salt which may have escaped reduction, and from the oxidizing action of the air during filtration. The great bulk of the iron, however, remains in solution in the ferrous condition. The precipitate is now collected on a filter, washed two or three times with water, and dissolved by passing dilute warm hydrochloric acid through the filter. If it does not seem sufficiently free from iron, the solution thus obtained should be put through the same process as has been just described, beginning at reduction with sulphurous acid. When filtered rapidly I have had as little as 0·1 grm. of peroxide of iron in the aluminum phosphate, and in no case have I required a reprecipitation. It is well to reduce the iron as much as possible.

An alternative method of getting rid of the great proportion of the iron is to add ammonia to the reduced solution till a slight cloudiness is formed; then excess of ammonium acetate, and boil for a few seconds. The whole of the alumina and a portion of the iron are precipitated, and are collected on a filter. No phosphoric acid is added in this case, and manganese remains in solution. More iron is brought down than in the first described cold method, and, when only minute quantities of alumina are expected, a second reduction and precipitation will most likely be necessary.

After obtaining a satisfactory precipitate (whichever method has been adopted), it is dissolved in hydrochloric acid, boiled with a little nitric acid to oxidize any protosalt of iron, nearly neutralized with pure caustic soda, and added to a considerable excess of the latter in a nickel basin. The mixture is boiled for a short time, filtered, the filtrate acidified with hydrochloric acid, and a large excess of phosphoric acid or phosphate of ammonia or soda added. I have found that the presence of at least two equivalents of P_2O_5 to one of Al_2O_3 are necessary to give rise to the normal phosphate of aluminum ($Al_2P_2O_8$). The latter is now precipitated by adding ammonia till a slight cloudiness is produced, and then excess of acetate of ammonium. Or the precipitation may be effected by simple neutralization with dilute ammonia till a red reaction ceases to be obtained with blue lakmoid paper. The aluminum phosphate is now collected on a filter, washed thoroughly with a hot 1 per cent. solution of ammonium nitrate containing about 0·1 grm. of the di-acid ammonium phosphate ($NH_4H_2PO_4$) per liter, dried, ignited, and weighed. If the aluminum phosphate is washed with water it partially loses its gelatinous form, and becomes tedious to filter. But besides this the precipitate is decomposed to a considerable extent, and a portion of the phosphoric acid passes into solution. For these reasons the precipitate must be washed in the manner described, when pure $Al_2P_2O_8$ is weighed, and may be calculated to alumina or aluminum as required.

The following are results obtained by the above process in solutions containing 3 grms. of metallic iron. To the iron solution a weighed quantity of pure ammonia alum was added.

Grm. of Al_2O_3 added.	Grm. of $Al_2P_2O_8$ obtained.	= Grm. of Al_2O_3 obtained.
0·0340	0·0800	0·0336
0·1135	0·2695	0·1132
0·1135	0·2703	0·1136

The presence of titanium is not injurious in the above process, as only slight traces of titanic acid are dissolved by strong caustic soda.

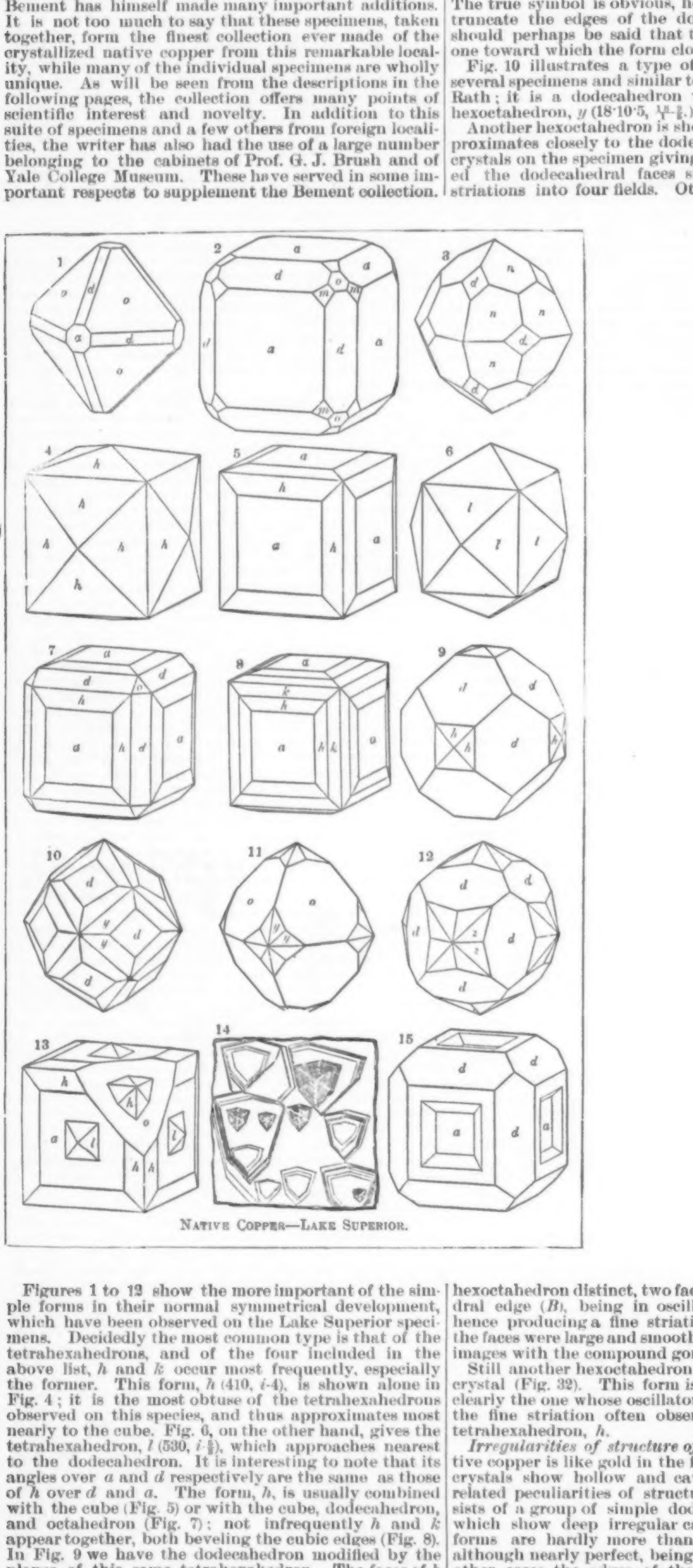
City Analyst's Laboratory, Glasgow.

—*Chem. News.*

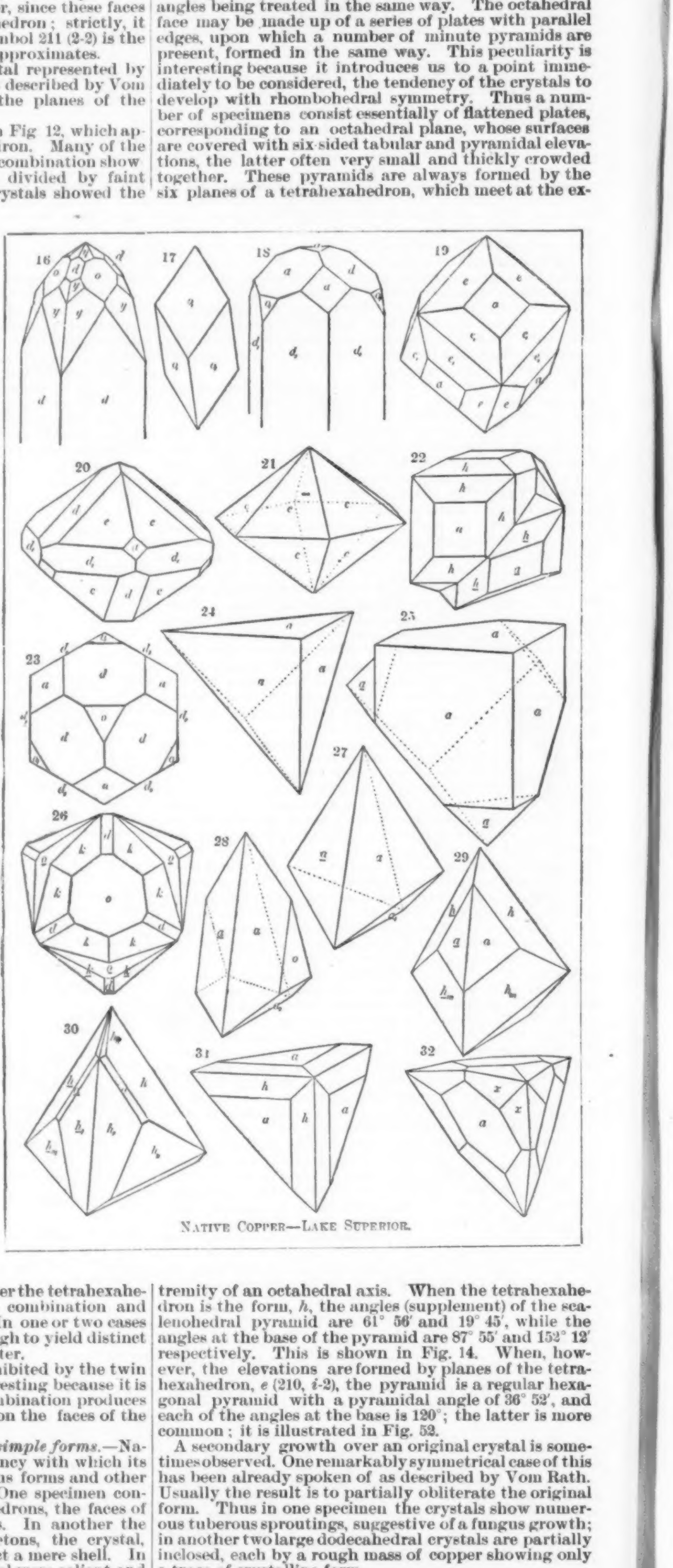
CRYSTALLIZATION OF NATIVE COPPER.

THE *American Journal of Science* for December contains a very able paper *On the Crystallization of Native Copper*, by EDWARD S. DANA. We make a few extracts:

Through the kindness of Mr. Clarence S. Bement, of Philadelphia, the writer has had an opportunity to make a careful study of his beautiful collection of specimens of native copper from Lake Superior, numbering upward of sixty. A considerable part of these were collected by Mr. Norman Spang, whose exceptional opportunities in this direction, extending over a number of years, were most zealously used. To these Mr. Bement has himself made many important additions. It is not too much to say that these specimens, taken together, form the finest collection ever made of the crystallized native copper from this remarkable locality, while many of the individual specimens are wholly unique. As will be seen from the descriptions in the following pages, the collection offers many points of scientific interest and novelty. In addition to this suite of specimens and a few others from foreign localities, the writer has also had the use of a large number belonging to the cabinets of Prof. G. J. Brush and of Yale College Museum. These have served in some important respects to supplement the Bement collection.



NATIVE COPPER—LAKE SUPERIOR.



NATIVE COPPER—LAKE SUPERIOR.

Figures 1 to 12 show the more important of the simple forms in their normal symmetrical development, which have been observed on the Lake Superior specimens. Decidedly the most common type is that of the tetrahexahedrons, and of the four included in the above list, *h* and *k* occur most frequently, especially the former. This form, *h* (410, *i*-4), is shown alone in Fig. 4; it is the most obtuse of the tetrahexahedrons observed on this species, and thus approximates most nearly to the cube. Fig. 6, on the other hand, gives the tetrahexahedron, *l* (530, *i*-$\frac{5}{3}$), which approaches nearest to the dodecahedron. It is interesting to note that its angles over *a* and *d* respectively are the same as those of *h* over *d* and *a*. The form, *h*, is usually combined with the cube (Fig. 5) or with the cube, dodecahedron, and octahedron (Fig. 7); not infrequently *h* and *k* appear together, both beveling the cubic edges (Fig. 8). In Fig. 9 we have the dodecahedron modified by the planes of this same tetrahexahedron. The faces of *h* are commonly striated in a direction normal to the cubic edges, owing to an oscillatory combination of the planes of a hexoctahedron which, as noted later, has probably the symbol 12·3·2 (6 4). Not infrequently, however, the faces of *h* are smooth and free from striations. The form, *k*, also occasionally shows similar striations.

Of the primary forms of the system, the cube alone is a rather common occurrence, and the dodecahedron occurs, though less frequently. The octahedron by itself, however, is not represented at all on the specimens in hand; this may be due in part to accident, but seems to show that the octahedral form alone is at any rate much less common than is the case with the other isometric native metals. Fig. 1 gives the nearest approach to the simple octahedron observed, and in Fig. 11 the octahedron is shown modified by the hexoctahedron, *y*. The octahedron is also prominent in the complex crystalline growth shown in Fig. 48.

Fig. 2 represents the only case in which the trisoctahedron, *m* (311, 3 3), was observed. This, as will be remembered, is a very common form with gold. Fig. 3 shows a combination which will be recognized at once as the common garnet form. It is, however, very rare with this species, and is only represented by one specimen. The faces of the trisoctahedron are slightly uneven, with the tendency to striation common with the species, and hence no exact measurements were possible. The true symbol is obvious, however, since these faces truncate the edges of the dodecahedron; strictly, it should perhaps be said that the symbol 211 (2-2) is the one toward which the form closely approximates.

Fig. 10 illustrates a type of crystal represented by several specimens and similar to that described by Vom Rath; it is a dodecahedron with the planes of the hexoctahedron, *y* (18·10·5, $\frac{18}{5}$-$\frac{9}{5}$.)

Another hexoctahedron is shown in Fig 12, which approximates closely to the dodecahedron. Many of the crystals on the specimen giving this combination showed the dodecahedral faces simply divided by faint striations into four fields. Other crystals showed the hexoctahedron distinct, two faces, over the tetrahexahedral edge (*B*), being in oscillatory combination and hence producing a fine striation. In one or two cases the faces were large and smooth enough to yield distinct images with the compound goniometer.

Still another hexoctahedron is exhibited by the twin crystal (Fig. 32). This form is interesting because it is clearly the one whose oscillatory combination produces the fine striation often observed on the faces of the tetrahexahedron, *h*.

Irregularities of structure of the simple forms.—Native copper is like gold in the frequency with which its crystals show hollow and cavernous forms and other related peculiarities of structure. One specimen consists of a group of simple dodecahedrons, the faces of which show deep irregular cavities. In another the forms are hardly more than skeletons, the crystal, although nearly perfect, being in fact a mere shell. In other cases the edges of the crystal were salient and the faces deeply depressed. One example is given in Fig. 15, where the cubic face is depressed, the sides of the depression being taken by the dodecahedral planes. The faces of the cubic planes especially are often thickly covered with quadrilateral pits formed by the dodecahedral planes (Fig. 15) or by those of one of the common tetrahexahedrons. Striated faces and faces with wavy, irregular surface are also frequently observed. Other irregularities, sometimes of an accidental nature, might be mentioned.

It is also common to observe cases of more or less distinct and regular elevations, triangular or quadrilateral or hexagonal, upon the larger faces. Sometimes these can be referred to known forms, but in others they are too indistinct to be determined. A vicinal tetrahexahedron on the cubic faces is occasionally noted. A prominent example of distinct and regular elevations is given in Fig. 13, where at the extremities of the cubic axes there are the projecting pyramids formed by the faces of the tetrahexahedron, *l* (530, *i*-$\frac{5}{3}$), a form which, as already stated, bears peculiar relation to *h*.

Fig. 13 also illustrates another point in the peculiarities of crystalline structure. One angle of the cube is here cut off by a broad octahedral face, at the center of which the planes of the tetrahexahedron, *h*, appear, forming a small six-sided pyramid. Other crystals show the same thing in greater or less symmetry of development, sometimes several of the octahedral angles being treated in the same way. The octahedral face may be made up of a series of plates with parallel edges, upon which a number of minute pyramids are present, formed in the same way. This peculiarity is interesting because it introduces us to a point immediately to be considered, the tendency of the crystals to develop with rhombohedral symmetry. Thus a number of specimens consist essentially of flattened plates, corresponding to an octahedral plane, whose surfaces are covered with six-sided tabular and pyramidal elevations, the latter often very small and thickly crowded together. These pyramids are always formed by the six planes of a tetrahexahedron, which meet at the extremity of an octahedral axis. When the tetrahexahedron is the form, *h*, the angles (supplement) of the scalenohedral pyramid are 61° 56′ and 19° 45′, while the angles at the base of the pyramid are 87° 55′ and 152° 12′ respectively. This is shown in Fig. 14. When, however, the elevations are formed by planes of the tetrahexahedron, *e* (210, *i*-2), the pyramid is a regular hexagonal pyramid with a pyramidal angle of 36° 52′, and each of the angles at the base is 120°; the latter is more common; it is illustrated in Fig. 52.

A secondary growth over an original crystal is sometimes observed. One remarkably symmetrical case of this has been already spoken of as described by Vom Rath. Usually the result is to partially obliterate the original form. Thus in one specimen the crystals show numerous tuberous sproutings, suggestive of a fungus growth; in another two large dodecahedral crystals are partially inclosed, each by a rough mass of copper showing only a trace of crystalline form.

Distorted forms and those showing pseudo-symmetry.—Cases showing irregular distortion are common, but among the simple crystals hardly more so than is the case with many other crystallized species. The distortion, on the contrary, usually exhibits a certain degree of regularity, being in the direction of one of the interaxes of the crystal, and thus giving rise to forms with marked pseudo-symmetry. Elongation in the direction of a cubic axis is frequently observed and, where symmetrical, produces pseudo-tetragonal forms as shown in Fig. 16; compare also Figs. 48 and 49, described later. Where the elongation is in the direction of one extremity of a cubic axis, the forms are hemimorphic in type and more or less irregular.

A symmetrical development of a crystal about an octahedral axis gives rise to forms with rhombohedral pseudo-symmetry, and these cases are so frequent and interesting that they are described at length below. Elongated wire and band-like forms of varied shape, often much curved and twisted, and showing some crystalline markings on the surface, are common, but these forms are generally very indistinct, and are hardly to be spoken of as crystals.

Crystals with rhombohedral symmetry.—It is an interesting fact in connection with the crystallization of the native metals, gold, silver, and copper, that they so often show a tendency to develop with rhombohedral instead of isometric symmetry. Many cases of this kind have been noted; one striking example has been recently described by the writer,* in which crystals of native gold had essentially the form of an acute rhombohedron ($4R$); these were arranged in parallel position, so as to form slender strings of rhombohedrons developed in the direction of a trigonal axis of the trisoctahedron (3-3), the other planes of the trisoctahedron forming a pyramid $\frac{4}{3}$-2 and obtuse rhombohedron $\frac{2}{3}R$.

Frequent examples of this tendency have been observed among the specimens of copper under examination, though none so marked as that just mentioned.

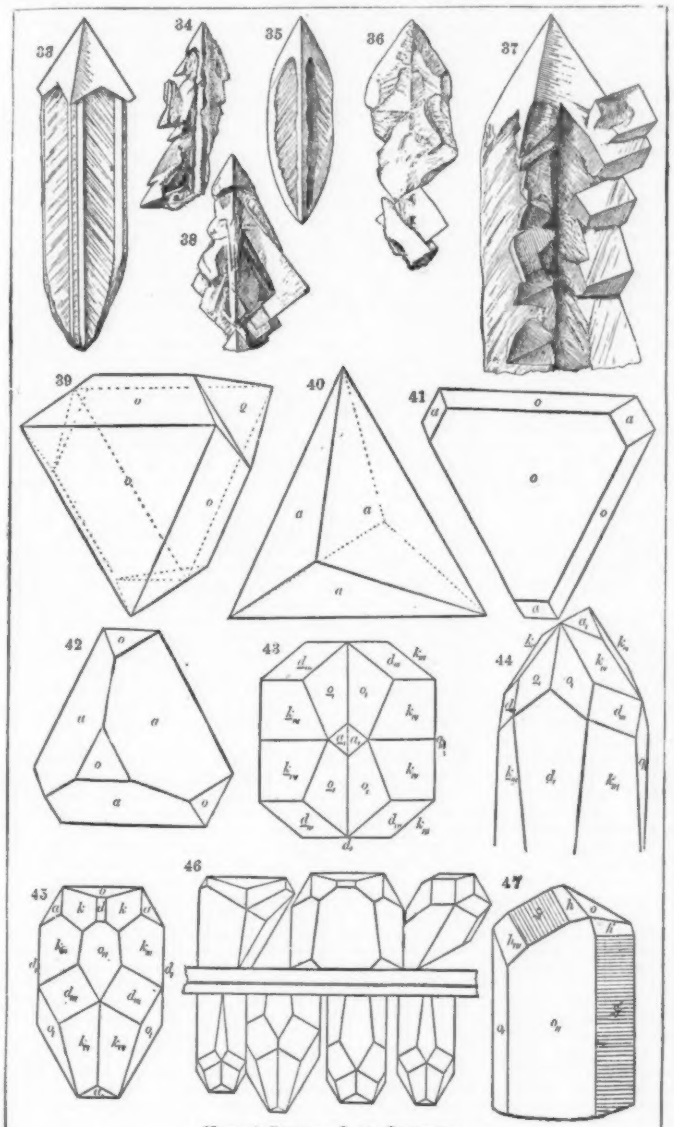
dron. Thus in Fig. 20 we have the planes of three of these forms together; this represents a simple crystal such as has been repeatedly observed, although twins of similar habit also occur.

One interesting crystal was observed which was a rhombohedral penetration twin of the tetrahexahedron i-$\frac{5}{3}$ (530) and cube. Of the faces of the first mentioned form, the twelve comprising in the rhombohedral position the negative scalenohedron $-\frac{1}{3}^{5}$ were prominent, those of the other scalenohedron indistinct; the cubic faces were all present, six above and six below. The twinning plane was the basal (octahedral) plane. The other tetrahexahedrons i-4 and i-$\frac{5}{4}$ are also developed at times, more or less distinctly, after the rhombohedral type, especially the former. The scalenohedron $\frac{2}{3}^{3}$ forms common six-sided elevations on the octahedral plates, as shown in Fig. 14, already alluded to.

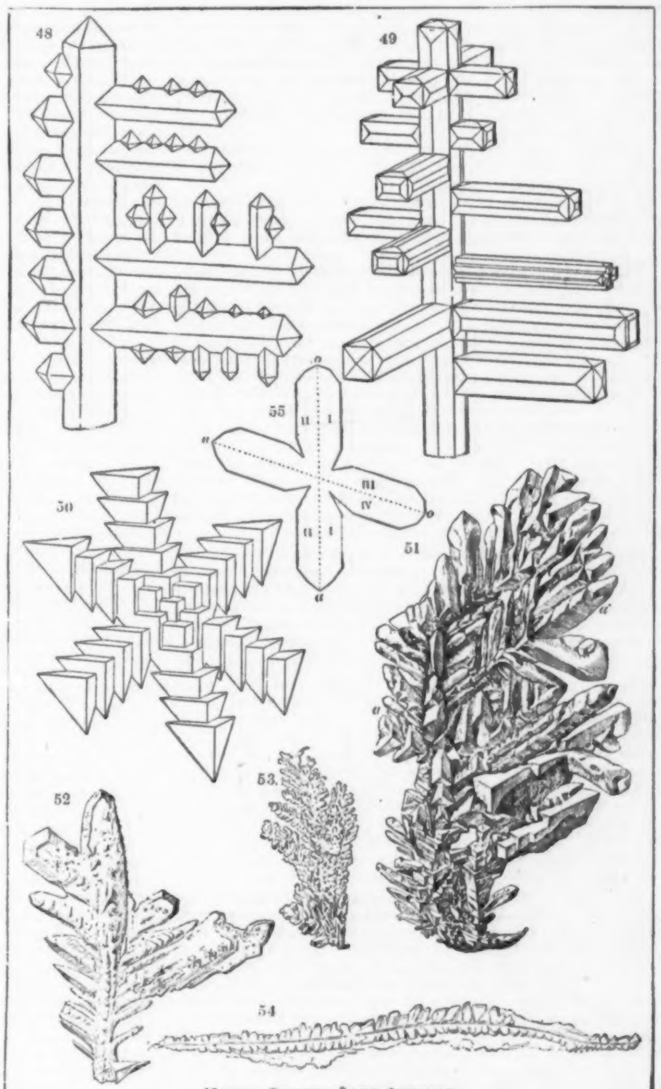
Twin crystals.—The specimens of native copper from Lake Superior occur very frequently in twin crystals, although the remark of Rose in regard to the Siberian specimens that simple crystals are rare would not be true of those under examination. The law of twinning is always the same—the twinning plane a face of the octahedron—but the variety and complexity of these twinned crystals is truly remarkable. The twins are, with very rare exceptions, contact twins; a few the orthorhombic position as mentioned below. These triangular twin crystals have a most anomalous appearance when they occur alone, suggesting a tetrahedron, or a hemitetragonal trisoctahedron, at first sight. One specimen from the cabinet of Professor Brush shows a broad surface of copper thickly sprinkled with very minute forms (1 mm. to ¼ mm.), some of them cubes, others tetrahexahedrons; and not a few are these triangular twins, like Fig. 24 or Fig. 31, and usually implanted by an acute trihedral angle.

Cases are rare, however, in which these cubic forms appear with this normal development. Generally they are elongated in a direction of a diagonal of the octahedral twinning face, and thus assume the symmetry of a (hemimorphic) orthorhombic crystal. Fig. 27 shows this twin in the position corresponding to the latter symmetry.

The way in which these twin crystals are developed will be clear from the following descriptions. One specimen of rare beauty and perfection consists of a group of elongated prismatic forms, the longest about 1½ inches in length. In each of them the extremity is formed by a smooth and symmetrically developed pyramid of the form just described, while the elongation in the direction of the diagonal of the twinning face is somewhat obscure. Fig. 33 represents* one of the



NATIVE COPPER—LAKE SUPERIOR.



NATIVE COPPER—LAKE SUPERIOR.

Among the specimens of native copper, two showed rather distinctly the acute rhombohedral form ($-2R$) of Fig. 17. The rhombohedral angle is here 70° 32′ and the plane facial angle 60° at the summit. The basal plane which is needed to fill out the eight faces of the normal octahedron was not distinctly present, and in fact the crystals were all lacking in sharpness, though there seems to be no doubt about the interpretation of the form.

Another specimen (Fig. 18) showed a long hexagonal prism i-2 (d_1) terminated by an obtuse rhombohedron $-\frac{1}{2}R$ (d), with also subordinate planes of the rhombohedrons R (a), $-2R$ (o_1); in a normal isometric crystal this would be simply a combination of dodecahedron, cube, and octahedron. A basal projection (Fig. 23) shows the rhombohedral symmetry very clearly. The tetrahexahedron e (210, i-2) is frequently developed according to rhombohedral symmetry, as was early noted by Hauy, Haidinger, Levy and others. It then corresponds to a hexagonal pyramid of the second or diametral series ($\frac{4}{3}$-2) and a scalenohedron 1^3. The twelve planes of the latter form are often subordinate or nearly absent, and the result is then the pyramid shown in Fig. 21; it is this pyramid which, as remarked before, so often covers the surface of broad octahedral plates. In such a form as Fig. 21, there is nothing to indicate whether we are dealing with a simple crystal or a twin. If two opposite pairs of these planes are extended, the result is an orthorhombic prism terminated by an obtuse pyramid.

Various more or less complex rhombohedral forms occur according as the planes just mentioned are modified by the faces of the cube, dodecahedron, or octahe-

penetration twins have been observed, as also a few cases of repeated twinning.

A penetration twin of rhombohedral type, with l (530, i-$\frac{5}{3}$) as the predominating form has been spoken of in a preceding paragraph. Another interesting case is shown in Fig. 26. The predominating form is the tetrahexahedron k, though the allied form, h, occurs subordinate, and the octahedron and dodecahedron are both present. From one point of view the crystal appears as a nearly symmetrical cruciform twin, while looking down upon the central octahedral face (as in Fig. 26) the habit is rhombohedral. It appears at first sight to be a compound twin, but the three octahedral faces in twinning position may all be referred to the same individual; the symmetry of the crystal is nearly equal to that of the drawing.

Fig. 22 shows a simple contact twin of the cubo-tetrahexahedron with the usual re-entering angles; this is similar to the forms figured by Levy. Contact twins of simple habit and normal development are very rare. Octahedral twins of the spinel type have been noted only in a complex growth similar to that represented in Fig. 54, and described later.

The spinel law applied to the cube yields the form represented in Fig. 25. This is the common type of twins among the Siberian specimens as noted by Rose. Among those from Lake Superior, however, crystals of exactly this form are very rare. Almost invariably, these cubic twins are shortened in the direction of the twinning axis, thus yielding a form consisting of two similar triangular pyramids placed base to base. This form, noted by Sadebeck* on the native silver from Kongsberg, is represented in Fig. 24, and again in Fig. 27, the latter in simpler of these forms, as true to nature as possible. Fig. 35 gives another quite small tapering crystal. In Fig. 37 the extremity of a more complex form is represented; here there is a cluster of cubes in parallel position on one side of the form. Other crystals have similar clusters on both sides in their respective twinning positions; they thus serve to reveal the true nature of the terminal pyramid, which, taken by itself, might be a serious puzzle, appearing, as it does, far off from normal isometric forms. The front edge, as seen in Fig. 37, is often made up of a series of jagged points formed by a repetition of the lower extremity of the trigonal twin. One of these crystals is so complex a combination of jagged projections on the edges, front and rear and on both lateral edges, as to hardly admit of adequate representation. Another specimen of scarcely less beauty than that just described consists of a group of twin crystals of the same type, but more complex and irregular. In them the common tetrahexahedron h (410, i-4) is prominent; four planes of this form, those about the cubic face 100, namely, 410 (h), $4\bar{1}0$ (h_1), 401 (h_{11}), $40\bar{1}$ (h_{111}), correspond respectively in the rhombic position to the pyramids 355 (1-$\bar{\frac{5}{3}}$), 533 ($\overline{\frac{5}{3}\text{-}\frac{5}{3}}$), 436 ($\overline{\frac{4}{3}\text{-}\frac{4}{3}}$), and 452 ($\frac{5}{3}$-$\bar{\frac{5}{4}}$); compare Fig. 30. Each of these crystals, as is also true of the smaller crystals on the specimen before mentioned, demands a special study before its form can be understood, and this is no easy matter, since exact measurements are out of the question. An adequate illustration of the subject would require an almost indefinite number of ideal as well as artistic figures, since the variety of form is so great.

* Am. Jour. of Sci., xxxii., 138, August, 1886.

* Min. petr. Mitth., i., 295, 1888.

* In the drawing of Figs. 33, 34, 35, 36, 37, 38, 51, 52, 53, 54, the writer has had the assistance of Mr. J. H. Emerton.

In Fig. 28 the trigonal cubic twin is shown in combination with the octahedron, not an uncommon form, though the crystals of this type are also usually more or less irregularly elongated, somewhat as in Figs. 33, 35, and 37. Fig. 31 shows a similar trigonal twin combined with the cube and part of the planes of the tetrahexahedron, h; this in the orthorhombic projection appears as in Fig. 29. Fig. 30 is another more complex trigonal twin, similar to Fig. 31, and Fig. 32 exhibits the same habit, but instead of the tetrahexahedron we have the hexoctahedron, x, already described.

Crystals of the type represented in Figs. 29 and 30, when developed after the orthorhombic type, form acute flattened spearhead crystals as shown in the drawings (Figs. 36 and 38). In these cases the crystals are flattened in a direction *normal to* the twinning plane, but in other cases the flattening is parallel to it, as described in the next paragraph. Very frequently on one or both sides some trace of the cube is shown by which the form can be orientated, and not infrequently the tetrahexahedral planes can be seen on the cubic faces in their normal development. The front edge is sometimes sharp and jagged in the way described, by the repetition of the lower angle of the trigonal twin. Fig. 34 shows this point well; it is drawn (like the simple Fig. 40) with the twinning plane parallel to the plane of the paper instead of normal to it, as in all the figures previously spoken of. These simpler specimens often show traces of the complex growth along lines at angles of 60°, and thus pass into such forms as that represented in Fig. 51. Other specimens show other forms of the same type, but differing most widely, according to the planes present and according to their relative development. In almost all of these, tendency to develop in orthorhombic symmetry is strongly marked.

Another type of twin crystal, somewhat related to those just described, but of very different aspect, is shown in Fig. 44.

Fig. 44 shows it in ordinary projection, and in Fig. 43 a basal projection is given; the rather close approximation to a tetragonal crystal is obvious at a glance ($o_{11}\ d_1 = 90^\circ$).

Fig. 45 is a projection upon the twinning plane. Here both parts, not, in fact, observed together on the same crystal, are represented together. In Fig. 45 the octahedral edge is placed above, to correspond with the symbols given. The forms shown in Figs. 43–45 are spoken of further in a later paragraph, where the method of grouping (see Figs. 46 and 54) is described. The understanding of this type of twin will be facilitated by reference to the simple forms in Figs. 39 to 42, all drawn with the twinning plane parallel to the plane of the paper. Fig. 39 is a simple octahedral twin of the spinal type; Fig. 40 the trigonal cubic twin already fully described. In Fig. 41 the octahedral twin is shown, but much flattened and with the cubic faces on the angles; this is also a copper form. Finally, Fig. 42 is the cubic twin with the octahedral faces.

Still another type of twin is represented in Fig. 47, which, like those already described, very rarely shows a re-entrant angle. The figure is a projection upon the twinning plane. The crystals of this type are elongated prisms, one edge formed by two octahedral planes ($o_1 \wedge \underline{o_1} = 38^\circ 56'$), and the other by the pseudo planes ϑ ($\vartheta \wedge \overline{\vartheta} = 90^\circ 54'$). The figure is placed so as to show the prismatic development, but to understand it, it must be turned so that the plane, o_1, is parallel to the same plane in Fig. 45; then h and h_{111} correspond to the tetrahexahedron, k and k_{111}, present there, etc. The pseudo planes ϑ and ϑ' are formed by the oscillatory combination of two adjacent tetrahexahedral planes, h and h_{111}, etc., and are in fact only a series of fine ridges. Were they real planes, the symbol for ϑ would be 81^7 (8-8) in the isometric system, or 7·10·7 in the orthorhombic position. Twins of this type are sometimes very regular and symmetrical, and again highly irregular, and varying much from the simple prismatic form.

Methods of Grouping.—The specimens of native copper very commonly show, instead of an irregular combination of crystals, a grouping in parallel position with sharply defined lines of growth. Two methods of grouping are most common. In the first, the lines of growth (the "tectonic axes" of Sadebeck) of the adjoining crystals or parts of crystals (sub-individuals) are the cubic axes; in the second, they are axes inclined 60° to each other and generally coinciding with the diagonals of an octahedral face, that is, the lines normal to its edges and bisecting the facial angles. A third method, quite different from the others, has also been observed.

The first method is common with many isometric species, and is represented here in several different forms. Thus one specimen is made up of small cubes grouped in this way. In another there are several series of octahedrons, each having a common vertical axis, and each octahedron made up of many small partial octahedrons (like Fig. 1), the whole specimen a wonderfully delicate and beautiful arborescent growth. Figs. 48 and 49 show interesting cases of the same thing. In Fig. 48 the predominating forms are the octahedron and dodecahedron, though the terminal crystals are sometimes as complex as Fig. 16. On this specimen we have sometimes a long wire with projecting points of small octahedrons; then more complex growths with branchings and rebranchings, and again a close, even network of rectangular ribs. In Fig. 49 the form involved is the tetrahexahedron h (410, i-4), and the lines of growth are uniformly the cubic axes. As will be inferred from the figure, the specimen is one of much beauty and interest.

The second method of grouping is, however, the more interesting, especially so in that the crystals taking part in it are generally twins. Here the twinning plane is the plane in which the lines of growth lie, and these axes are three lines crossing at 60°, and situated as described. The explanation of an analogous method of grouping was given by Rose in his description of the complex growth among the Siberian crystals already spoken of. The Lake Superior specimens differ from the Siberian in that, although the branching is also at 60°, the directions are almost always those of the *diagonals* of the octahedral face, not of the *edges*. This statement is true of all the Lake Superior specimens the writer has had the opportunity to examine, with a single exception, while one beautiful specimen from Siberia in Mr. Bement's collection agrees with the description of Rose. It may be noted here that Sadebeck describes both these systems of "tectonic axes" as occurring in the dendritic growths of native silver, and he also mentions having observed the diagonal method of growth himself in copper. The Lake Superior specimen described by Vom Rath is stated to have conformed to the method given by Rose.

An ideal representation, showing the common method of growth, spoken of, of the trigonal cubic twins, is given in Fig. 50. The actual forms are, however, most complex, for instead of simple cubes we may have either one of the commoner tetrahexahedrons or a combination of one or more of them with each other or with the cube, octahedron, and dodecahedron. Moreover, we have sometimes an open series of cubic twins, and from these we pass to more compact forms and finally to specimens which are simple plates with broad octahedral surface showing the characteristic spear-shaped twins only occasionally at the edges and with the hexagonal lines of growth only slightly accentuated. In the latter cases the octahedral surface is commonly covered over, often very thickly, with hexagonal elevations formed by one of the common tetrahexahedrons as already described. Still further, a number of these branching dendritic growths may be grouped in slightly diverging position about a common center, thus producing arborescent crystallizations of great beauty.

The twinning is also often somewhat complex; for it may be not simply a case of a single twin growth with the upper surface in twinning position with respect to the lower, but on the same side any one of the tectonic axes may be taken by a series of cubic twins in reversed position to those adjoining, or a single crystal in twinning position may appear in the midst of the others.

Fig. 51 shows (⅔ natural size) one of the finest of these remarkable specimens. It illustrates admirably the method of growth and the remarkable complexity of the resulting forms. The spearhead forms at the extremities are here well seen. It is to be noted also, in illustration of a point just made, that for the lower part of the specimen the crystals are in twinning position with reference to the majority of the others, and this is true also of isolated cubes at various other points, as at a, a.

Fig. 52 shows one of the tabular forms in which the octahedral plane predominates, and it is only on the central and branching ribs that the other—tetrahexahedral—forms are distinct. The surface is thickly covered with hexagonal plates and low pyramids, which the drawing only in part represents.

In Fig. 53 a partially satisfactory representation is given of a very delicate moss-like dendritic crystallization, which is especially interesting, because careful examination proves that the tectonic axes here are situated diagonally with reference to the common method. In other words, it is like the forms figured by Rose. The specimens are nearly an inch in length and very thin and fragile. The octahedral surface is prominent, though cubes in thin plates, or in normal forms, project from it, sometimes in one position, sometimes reversed—over one surface there are a number of tetrahexahedrons with rhombohedral (scalenohedral) development implanted on the octahedral surface; these are also in both positions.

A novel and interesting method of grouping, different from those described, is represented by several fine specimens. The crystal individuals taking part in it have already been partially described (see Figs. 43, 44, 45). The larger specimen, as shown in the drawing, Fig. 54, consists essentially of a long, slightly curved line, deeply grooved along the center, from which project above and below, in two directions crossing at angles of 70° 32′ and 109° 28′, a series of small (2 mm.) partial crystals. This line of elongation is one edge of the twinning octahedral plane. The crystals above and below form the two parts of Fig. 45. Those below terminating in the cubic twinning edge have a rather constant habit, as shown in Fig 46. The crystals above, however, which terminate in an octahedral twinning edge, vary much, and have a marked tendency to develop in forms similar to those below by elongation to one side in a direction normal to the cubic edge. This is suggested by the forms in Fig. 46; but other crystals are very much more elongated, and incline to one side at a sharp angle. Others of these crystals are broad plates showing but few planes except at the edges.

The smaller specimens of this type show also more distinctly a second similar line about the same axis, and crossing the others at the octahedral angle of 70° 32′. Fig. 55 gives a cross section in outline, and makes clear what the relations of the two series are. The individuals I and II are in twinning position with the octahedral edge above. The individuals III and IV are also in twinning position with the adjacent octahedral plane as twinning plane, and in such a manner that the first twinning plane is parallel to the octahedral face of III which forms the edge of III and IV. Another specimen showed the same method of complex growth, though the component crystals were simpler, some of them being simple spinal twins like Fig. 39. The lines in all these cases, when naturally terminated, taper off to a rather fine point.

[AMERICAN NATURALIST.]

CAUSES OF FOREST ROTATION.

By JOHN T. CAMPBELL.

I.

IN a letter recently received from Dr. S. V. Clevenger, he mentioned a case coming under his own observation on the North Pacific railroad, in Minnesota, near Mille Lacs, where the railroad company cut the pine timber off of their own alternate sections for railroad ties and other purposes. This pine forest was succeeded at once, to all appearances spontaneously, by oaks.

I have often heard North Carolinians say the same thing about old fields in that State, when abandoned as worn-out land, that some timber different from that which had been cut off when clearing the land at first would spring up spontaneously, or appear to be spontaneous.

I can speak only for my own locality, not having observed any other. Here (west central Indiana) we have in many localities a prevailing species of timber, but no species that exist to the exclusion of all others, as is often the case with pine. But of our prevailing timber, or any other kind, sugar maple excepted, none seem to be reproducing their kind in their immediate vicinity. For reasons which will follow, I surmise that nearly all forest trees bear and shed leaves which are unfavorable to the sprouting and growing of their own seeds. The most notable instance I can now think of is the red cedar, introduced into this vicinity from the north and northeast about forty-five years ago for ornamental purposes. I don't remember at what age they began bearing seed, but I think as early as ten years, counting them to have been three years old from the seed when transplanted here.

Until certain kinds of birds began to eat their seeds, they were not found growing wild in the forests. I do not know what birds eat the seed, but evidently all do not, else they would have been planted as soon as the parent trees bore seeds, which was not the case for fully fifteen years afterward. When these seeds pass through the craw and intestines of birds, they are prepared to sprout when they come in contact with ground of the proper degree of moisture. Nurserymen, when they gather them direct from the trees, are obliged to put them through some process of scalding before planting. The birds drop them promiscuously over the country, where they have been appearing within the past fifteen years numerously, and only rarely before about that time. They are hardy trees, and bid fair to become one of the forest trees of the future in this part of Indiana. It is reasonable to presume that these seeds would be more abundantly dropped under and very near these parent trees than elsewhere, for quite probably the birds that nest in these trees eat their seeds. Yet no young cedars are ever seen to sprout and grow there.

The same is true (*i. e.*, not growing their young within the radius of their leaf-fall) of the white pine, firs and other evergreens transported here for ornamental purposes. Some of the older ones are twenty inches in diameter, and have borne seeds many years.

I have long observed that the seeds of forest trees shed upon the forest leaves, sugar maple excepted, cannot sprout. This is very specially the case with the American poplar seeds. Yet I often find in the woods clusters of young poplars, varying in age from one year to sixty and seventy years. Last year I found out how this comes about. If seeds happen to fall on the bare ground of the right degree of moisture, they at once take root and grow. If about the time these seeds are falling there should be a hog in the woods, and he should have an appetite for ground worms, he would thrust his strong snout through the leaves into the ground and cast up fresh earth in a very promiscuous manner, and every poplar (or other) seed that should happen to fall on that fresh ground would stand a good chance of growing. I saw young poplars just barely sprouted under the above circumstances, while at the same time other and brother seeds had fallen on the leaves near by, where they lay dead and as dry and crisp as smoking tobacco.

Sometimes squirrels, hares, ground squirrels (chipmunks), dig through the leaves into the ground for food which they find there, I presume, and these places give a chance for one or more seeds to grow, and the hoofs of heavy bullocks (and in times past the elk and buffalo) have made deep tracks through the leaves into the ground, which would give a like chance, while the coating of leaves would prevent the growth of all the rest. The hogs were brought here at the very earliest time of settlement, turned loose in the woods, where they multiplied rapidly, becoming wild, ferocious, and more dangerous to man than bears, wolves, or panthers. Many of these clusters of poplars correspond in age to this time.

In Rockville, Indiana, where I reside, the river bottom soft maple is very generally planted for a shade tree, mainly because of its rapid growth. Many of these are ten to twenty inches in diameter at the butt, and have been bearing seeds for years. The seeds of this tree must find favorable growing conditions as soon as they fall or they are lost, for one day's baking in the hot sun kills them. They must have a steady moisture with warm, but not hot, sunshine. The trees bore a bountiful crop of seed last May, and of the first that matured and fell, I tried to sprout about a dozen by placing them in good ground and watering every day for several days. But as I could not give them all my time, they dried up between waterings and died. After these had died, there came a threatening, blustering storm one Sunday evening about sundown, which shook off the remaining soft maple seeds. They are so abundant that they gave the streets a buff color where they fell. The wind was followed by a light, steady rain, which continued several days, alternating with sunshine. This was favorable to sprouting these seeds; they came up all over the streets, yards, and gardens as thick as weeds in a neglected field, a thing that never happened before in the twenty-two years I have resided in the place. Those in the street the cows ate up; those in the gardens were weeded out; and those growing elsewhere were killed by the following summer drought.

On the south end of my garden, where a cellar drain terminates, the proper moisture was maintained through the drought, and there stands a thick cluster of them, the only survivors, so far as I know, of the millions that sprang up last May. After these trees are three years old they can be successfully transplanted into any kind of soil we have here, and seem as hardy as any dry-ground tree; but during their infancy the conditions *must* be as before stated, or they die. So I think it is clear that this tree will never be self-planting, except along the low, moist bottom of the streams where we find it native.

The hard sugar maple does plant its own seeds within the radius of its own leaf-fall. In 1884 there developed a local rain in the southeast quarter of this (Parke) county which continued showery for several days, alternating with sunshine, just as the sugar maple seeds were falling. The result was as in the case of the soft maples last May; all the seeds sprouted. As this favorable condition did not happen when the other trees were shedding their seeds, the result in that part of the county is that the sugar maples are a hundred to one of all the other young trees combined, and the deep snow and cold winter that followed, making a hard crust on the snow, prevented the sheep, cattle, and rabbits (hares) from browsing them down, though it starved thousands of rabbits, as their bones, found in hollow logs and trees, abundantly attest; but it saved the young sugar maples, till they are now large enough to be safe from every enemy except man. If he were out of the way for 150 years, about all the present forest trees will have lived out their time, and these

young sugar maples would be almost the only trees of the forest in the area where a rain happened to fall with the seed. In the other three quarters of the county that state of things would not exist, for there only the lucky seed that fell where a hog had rooted or a bull had trodden has made a tree, and this luck was as favorable to other seeds as to the sugar maple. These maple seeds send rootlets right down through the coating of leaves into the ground; and I have seen, over an area of many acres at a time, a maple sprout for every four inches square, or nine to the square foot, none seeming to have missed sprouting. In replanting the ground where the present forest has been cut away, the sugar maple makes the least show of all the forest trees. As an infant it seems to thrive best in the shade of older trees.

How the oak can take the place of pine where there are no oaks in the vicinity to bear acorns, I am not sure; but it is easier and more rational to believe that there is some natural agency for transporting the seed of the apparently spontaneous new tree than to believe it to be really spontaneous, whether we understand the transporting agency or not.

One of the most industrious and persistent seed-transporting agencies I know of is that ubiquitous, energetic, rollicking, meddlesome busybody, the crow. Did you ever take a young crow and raise it as a pet? Please do so once, and you will have more information about crows than I could give you in an entire number of the *Naturalist*. They become very tame, and after they are able to fly it seems to be the delight and work of their lives to pick up and carry from place to place any and every article which is not too heavy for them. After a pet crow has had a little practice, he is as expert at tricks of legerdemain as a showman. He will steal a spool of thread, a thimble, a pair of scissors, a paper of pins, or what not, right before your eyes, and as he flies away will tuck it so adroitly up under his tail feathers that you can't see it. He makes a deceptive grab as he starts to fly, and by taking a few steps as if to give himself a little momentum to start his flight, and one of these steps he will plant square on the article he intends to steal, when his claws close round it and off he goes. Perchance he will alight only a few yards distant on the ground beside a chip, which chip, as he alights, he will so quickly and adroitly turn over with the other foot as to cover out of sight the article he has taken. He will then take a few steps about the chip with his toes all properly radiating, purposely to show you that he does not hold the missing article in his claw. Unless you are acquainted with his tricks, you would concede that he had not taken your thimble, so adroitly is the trick performed. Then he is ready for some new mischief. Off he goes to the chicken yard, where a hen and her chicks are scratching for bugs. He alights plump into their midst. The little chicks scream and scamper for shelter. The old hen, with her feathers all awry, dashes at him as if she would tear him into strings, but just as she gets in striking distance the crow opens his mouth and caws loudly right into her face. She stops abruptly, hesitates, and slowly backs off. Then comes the cock of the yard, like a charge of cavalry, to drive the intruder from his premises; but as he too gets in striking distance, the crow opens his mouth about three inches wide and caws so loud, right into the cock's face, that he can be heard a quarter of a mile. The cock too stops suddenly, and his look of surprise and amazement is most amusing. His wrothy feathers gradually smooth down and he takes a few steps cautiously backward, then whirls and runs back under the rose bush, and there tells the hens how the crow acted—like Irving's Knickerbocker soldiers who were sent up the Hudson to capture a fort, and who had nose, thumb, and fingers all wiggled at them at once over the wall by the garrison, which was such a strange and unexpected proceeding that they hastened back to headquarters to report what had taken place.

I had a pet crow two years ago that cut so many tricks in his way that a neighbor shot him one morning. Afterward, in cleaning the leaves out of my eaves troughs, various of our own and our neighbors' articles were found in the troughs and on the roof.

The crow in his wild state is all the time busy at some such work as I have described. I cannot discover that he has any design in this busy, meddlesome mischief. If there is design in his work, it is back of the crow in the Great Superintendent of nature's processes. I have seen crows gather by hundreds and have a regular powwow, a mass convention where they seemed to discuss measures and appoint officers. I have heard their cawing more than a mile distant. At length they get through, by finishing their work or tiring of it, and disperse. As they start to fly away many, if not all, will drop something. I have found these to be acorns, walnuts, hickory nuts, buckeyes, sycamore balls, sticks, egg-shells, pebbles, etc. As a crow leaves an oak he will pluck an acorn, which he may carry five miles and light on a beech tree, where something else will attract his attention, when he will drop the acorn and may be pluck a pod of beech nuts and fly away somewhere else.

The squirrel is also a nut-transporting agent. The hog will eat his nut where he finds it, but the squirrel must find some suitable place to eat his nut, like some fastidious boarders I have known, who would not and could not eat if they failed to get their own conspicuous place at table. The squirrel will select his nut, take it in his mouth, skip along a few yards, pause a moment, then a few more skips and pause, preferring a fence or fallen tree to the ground for his roadway. He will sometimes carry his nut several hundred yards, not to his home, but to some conspicuous tall fence stake or dead projecting limb of a tree, on which he sits on his haunches, his tail curled over his back, and in this striking attitude he complacently gnaws through the shell of his nut to get the kernel. It will sometimes happen that just as he is ready to begin on his nut a hawk will swoop down after him, and his complacency is glad to drop his nut and flirt down to the under side of the limb for protection. This nut may fall on good ground and make a future great forest tree. He will be chased by a dog, fox, or hawk sometimes while on his way to his eating place, and involuntarily plant an oak, a walnut, or hickory. The partition fences across our cleared farms and stumps out in the fields have many such planting of oak, walnut, and hickory, far from the trees that bore the nuts, which I attribute to the crow or the squirrel.

I know a place about four miles southwest of here, where a low place in a field was too wet to be plowed, and has grown up full of young burr oaks, but there is no parent tree anywhere near, not near enough even for high winds to carry such acorns. Such acorns sprout only in wet ground. I think this grove of burr oaks is the result of a frolic of the crows. They had a previous frolic on a burr oak, and in leaving it for this place each carried an acorn, as is their habit.

II.

Since my article on the above subject appeared in the June, 1886, *Naturalist*, I have received a good number of letters, both from acquaintances and strangers, some making further inquiry about some phases of the subject, some offering explanations different from mine to account for forest rotation, and still others ridiculing my theory that seeds, especially nuts, are carried by crows, woodpeckers, and squirrels sufficient to plant such large districts of young forest trees as suddenly spring up where forests of a different timber have been cut away, or such as have sprung up on the prairies of the Wabash River second bottoms since the white settlers have stopped the burning of the prairie grass.

I have been struck with the number of persons who seem to believe (as indicated by this correspondence) that when a forest is swept away by the ax, fire, or a blight, a different kind of forest springs up spontaneously out of the soil. I admit that it has much that appearance. Especially does it appear to be so with weeds and grass, but the seeds of the latter are so small that it is about impossible to keep track of them; but forest trees that grow from nuts we may more easily observe, and if we find that their seeds have been carried far beyond their fall from the parent trees, and planted so as to produce trees, we may, I think, take the planting of weed and grass seeds for granted.

Dr. Clevenger, of Chicago, in a letter says, in speaking of the oak following pine in Minnesota, where the latter was cut off of the railroad sections: "My idea was that during hundreds of years the chemical constituents of the soil having been drawn upon for the sustenance of pine, something near exhaustion had occurred or, at least, enfeeblement of the ground, and that a seed which in its development required different soil constituents, or complementary ones, would be most apt to succeed the pine. The oak seems to be universally the terebinthinate follower in Scandinavia, Scotland, England, America, and elsewhere. . . . For hundreds of miles along the Minnesota division of the North Pacific railroad, the alternate sections of cleared and uncleared forest presented, the year after clearing, a checkerboard aspect of young oak and old pine. Then why should beeches and larches everywhere follow the oak destruction? It seems to me the true explanation comes in climatological changes as minor, and soil chemistry changes as major, causes."

I admit the puzzle the doctor produces. Perhaps neither of us is right in accounting for forest rotation. My theory—which I have offered only as a suggestion or query—that perhaps most forest seeds will not grow in the leaf-fall of the parent tree, and that nuts are transported long distances and in great numbers by crows, woodpeckers, squirrels, etc., while it is possible, and seems to me probable, may not be the *fact* that accounts for oak following pine in Minnesota in the manner stated. But I must be allowed to believe a few days longer that an oak starts from an acorn.

It is remarkable how often we all (and many very intelligent and scientific persons are included) ponder, wonder, and speculate about a phenomenon, the evidence to solve which lies at our feet. If the doctor, while on the ground, had examined a few of the infant oaks, I think he would have found an acorn attached. And if he had, the only unsolved question remaining would be—How did the acorn get there? As it is, the first question to settle is whether the oak came from an acorn or spontaneously from the ground. In my locality the acorn and the dark mould cast which it leaves in the ground can be identified as late as the third year after sprouting.

Professor George K. Greene, of New Albany, Indiana, writes: "If you were to visit this section of country, in Harrison county, Indiana, called the 'barrens,' you would find an area of several thousands of acres all grown up with post oaks (*Quercus obtusiloba*). There are citizens residing in the vicinity who came there when there was no timber on the ground. Can your crows and squirrels account for this?"

I will answer this by describing the work of the crows in this vicinity about the year 1847. John Williams loaded a flatboat with chickens for the New Orleans market. Such a boat could, and his probably did, carry three thousand chickens. Of these, two thousand would be hens, as the farmers generally kill the males for their own table use. This boat, in running over Manwarring's mill dam, sprung a leak, and sank so fast that all the chickens had to be turned loose in the woods on the north side of the creek, and about half a mile above where it enters the Wabash River. There the hens laid about two thousand eggs a day for about a week, while the boat was being repaired, making about fourteen thousand eggs laid. The crows carried these eggs—how many I can't say—southward across the creek and buried them in Huxford's field, more than half a mile distant. That was in early spring. Soon after Huxford and his boys broke that field for corn, and the plow turned up hundreds of eggs, and perhaps thousands, as they were too numerous to think of counting. When the broken ground was afterward furrowed off for planting, many more eggs were exposed, and after the corn came up and was being plowed, hundreds more were exposed. Very probably the plows exposed less than two-thirds of those buried, as the plow cut would go below the depth likely to be buried. Huxfords took their dinners to this field, and they cooked the eggs thus found by the fire where they made their coffee, and the eggs remained good till the first plowing of the corn in early May, when they became tired of them and ceased to notice them further. John Huxford, a wealthy farmer of this county, and one of the boys who plowed the field, told me about finding and using the eggs.* The "stoving" of Williams' chicken boat I myself remember, as I then lived with an uncle on Sugar Creek, not more than three miles distant from the field.

Might this not be a good way to preserve eggs? The field was dry, alluvial, rather sandy soil.

Suppose the eggs had been acorns, and the field had not been disturbed with the plow, and also suppose the rank bottom weeds had exercised polite forbearance and kept out of the way; would there not have been founded a dense oak forest?

In the fall of 1876 and winter and spring of 1877, I was surveying a line of railroad in Southern Illinois. About five miles west of Benton, the county seat of Franklin county, the line of survey cut across peninsulas of prairie extending into the timber, and likewise peninsulas of timber extending into the prairie. These are called arms of prairie and points of timber. The old timber followed up the small streams into the prairie.

The buffalo and deer, in past time, kept the grass eaten and tramped down along the water-courses where they drank, thus greatly reducing, if not entirely preventing, the destructive prairie fires from consuming the young trees. Hence the points of timber following up the streams. In the locality I am describing, the timber was almost exclusively white oak. After the settlers stopped the prairie fires, these points of timber began to widen and crowd on the prairie, and in the last forty to fifty years the young oaks had extended out about a half mile from the old timber, and they ranged in height from about fifty feet next to the old trees to the infants just emerging from the ground out at the frontier.

At that frontier I saw oaks, not over four feet high, bearing acorns, keeping the seed right up to the front. In Indiana, where it is unnecessary for trees to perform the parent functions so young, I never saw a white oak less than thirty feet high bear acorns, and not then among older oaks.

In the second or terrace bottoms of the Wabash River, when the whites first settled them, they found most of them to be prairie, grown up in weeds. The prairie grass had not yet got possession of the ground, except in patches. They found also scattering and stunted white oaks, black oaks (*Quercus nigra*) and jack oaks (*Quercus ferruginea*). The Indians had, for an unknown time, burned the prairie weeds and grass, which not only killed the infant trees, but greatly injured the old ones, especially on the south side, where to-day, notwithstanding seventy years of protection from fires, they still show the scars, though generally healed over, and on their sawed-off stumps can be read the true history of their lives.

After the prairie fires were effectually stopped, a dense growth of young trees sprang up, and to-day they are fifty to seventy feet high, vigorous and thrifty. Last year I had occasion to hunt for piling timber in a grove of this timber on the Walker farm, about twelve miles north of Terre Haute. Some one had sawed down many of the trees, for some purpose, and while waiting for a team I counted the age of the trees by the concentric annual rings on the stumps. Notwithstanding that their diameters varied from six to twenty-two inches, every one of forty I counted was sixty-four years old. Their ages tallied with the date when the fires were suppressed. The prevailing young trees in that grove were jack oak, though there were a few white oaks, hickories, poplars, and black walnuts among them, and these were as tall and thrifty as the prevailing kind. The prevailing old, scattered, stunted trees of that locality were white oak, but the young white oaks showed no lack of thrift and vigor in growing by the stumps of their parents.

In Ohio, on the east side of the Big Miami River, and about a half mile south of the line between Hamilton and Butler counties, old Major Cilley (a relative of the Cilley who fought a duel with Graves, in Jackson's time) undertook to clear ten acres of land on the Miami hills. This was about seventy to ninety years ago. I am not sure as to exact date. He felled the trees when in full leaf, and after they were well dried, fired them and burned everything clear. The next spring the black locusts sprouted as thick as weeds in a field, wherever the fire had been. For some reason the ground was not plowed, and the trees soon grew to be valuable timber, as it makes the best of fence and gate posts. There were a few parent black locust trees in the vicinity, but they were by no means the prevailing forest tree there. Their seeds resemble an apple seed, are very hard, and must undergo a process of scalding, scorching, or very hard freezing and then have a clear field before they will grow. Their seeds, being small, are easily carried by the wind, and are so impervious to ordinary weather influences that they may lie among the forest leaves many years, and when some subsequent favorable condition transpires, as the burning of Cilley's fallen timber, they sprout into life and make a locust forest.

In further consideration of Dr. Clevenger's idea of soil exhaustion as the cause of a change in the kind of timber, I will say that in all the pine forests I ever saw, the individual pine trees showed no more evidence of enfeeblement, as I should expect in case of soil exhaustion, than do the trees of the forests here, where all kinds grow promiscuously together. A few years would test this question, if somebody would plant an infant pine and oak together near a grown oak, and the same near a grown pine. There should be several of each plant to guard against accidents to either kind spoiling the comparison, and then observe their comparative progress in a few years. Has anybody ever done this? Will somebody who has an opportunity please do so?

* Since writing the above, I have seen and talked again with Mr. Huxford, and find that I am mistaken about an immaterial fact. It was not the boat that was injured on the mill dam, but one that was built there several years later. The farmers brought their chickens in before the boat was ready, and turned them loose in Cheesem's orchard, on the south side of Sugar Creek. The crows carried the eggs across to the north side of the creek, and buried them in the Chatsey field (which was sold for taxes, and Huxford bought it). The balance of the statement is correct. I presume I inferred the stove boat, because it occurred at the same place. I have told this circumstance often, and have found people who manifested some skepticism, because of its rare occurrence. But I have also found several other persons who have found eggs buried in the ground, and they also say the eggs appeared to be sound when found. Hens, when not too much confined, hide their nests, and the cautious crow does not venture into ambush to find them. It was *then* rare that chickens were crowded together, but uncooped, in such numbers, and since shipments are made by railroad it never occurs. So of course the case is a rare one. Any one acquainted with the habits or nature of the crow knows he is much given to carrying things from place to place and burying them.

HAUNTS AND HABITS OF THE GREAT LAKE SALMON.

By G. ARCHIE STOCKWELL, M.D., F.Z.S.

IN writing of the Great Lake salmon, I am prompted to do justice to the *great* "Mackinac trout," so called, a creature of profound depths and cold waters, of

which little is known, and that is found only in latitudes north of the *forty-fifth* parallel, and not the vapid, tasteless, yellow-meated salmonoid of medium size, universal distribution, and shoal waters, the product of pound and lesser gill-nets, that obtains in markets and upon hotel tables under the same name. Science, to be sure, proclaims the identity of the two forms, but science is by no means infallible, and unlike coloring, habits, and haunts, to say nothing of the distinctions made by the human palate, are all suggestive of specific derivation. It is the latter, the salmonoid, as found in the superheated and shoal waters of Lakes Ontario, Erie, and St. Clair, and its cousin of southern Lakes Michigan and Huron, that is commonly selected by the icthyologist as a type and for illustration, and that has brought reproach and disrepute upon the better fish; and like error led the brilliant, cynical, and dogmatic Herbert (Frank Forester) to unreservedly pronounce the "Mackinac salmon," as he prefers to designate him, "coarse, flabby, and at once rank and insipid, if such a combination can be imagined."

Again, for some unknown reason difficult to surmise, in America all somber-hued trout have obtained the prefix of *salmon*, a term that definitely and specifically belongs alone to the sea trout, *Salmo trutta*. It also has been, and frequently now is, applied to *Salmo amethystus* or *namaycush* (both names obtain), which has led to further confounding him with the coarse and hideous "laker" of Eastern waters and ponds.

The external differences between Mackinac and the yellow lake trout are by no means remarkable. But the latter breed on sand and gravel banks and bars, and not infrequently ascend the rivers considerable distances for the same purpose. They are to be encountered in all situations over shallows, even to clay and impure bottoms, frequently in considerable schools; within certain limits are strictly local in habit; and above all survive, and even thrive, under the infliction of intestinal parasites, to which they ever play the host to a degree that fishermen dare not feed their offal to swine because of the results that accrue, the least of which is the disease known as *measles*. Amethystine trout, on the contrary, are exceedingly cleanly, particularly in habitat, and aristocratic in mien, wanderers by nature and choice, inhabitants only of extreme depths and solitary in habit, save only for the brief period when led by instinct to provide for the perpetuation of the species, they gather to spawn beside giant reefs that abruptly rear their jagged sides for hundreds of feet above the bed of midlake, yet fail to touch the surface by many fathoms. Moreover, they never survive the attacks of *entozoa* that speedily develop the peculiar form vulgarly denominated a "*racer*," that may be held in some degree the analogue of the *kelb*, a creature to be encountered only in summer and autumn, disappearing in winter with the formation of ice.

A victim to disease most foul, the "*racer*" is readily recognized by his long, thin, fleshless body covered with loose and flabby skin, a greenish or grayish-brown fungus-like mould formed upon the gill covers, branchial fringes, and upper thorax and throat, and a manifest inability to float elsewhere than along the surface, owing to an enormously distended air bladder. He escapes the enmity of man only to suffer a miserable and lingering death, either through starvation, by being crushed in the ice, or torn by eagles, ravens, and hawks, the latter as a reward for their cruelty and rapacity being in turn inflicted with myriads of *cysticerci*, *cestoidea*, or *trematoda*.

Always a prey to the pangs of hunger, the unfortunate will snap at anything, from insects to a walking stick, though in a most idle, spiritless way, and that he is unable to swallow would seem to appear from the fact that his stomach is invariably found devoid of anything that could offer nourishment.

Accepting the statements of Mitchell and La Houtain, lake salmon may attain almost any weight up to *one hundred and twenty or twenty-five* pounds. Forty pounds, however, is a somewhat unusual limit in these days, though on two separate occasions I had the pleasure of viewing specimens respectively thirteen and twenty-three pounds heavier; and no later than the latter part of the last decade, I am informed that one of plump one hundredweight was served at the table of the Roman Catholic priest of Marquette Parish, Lake Superior, the occasion being a banquet given in honor of a number of visiting brethren of the cassock and missal.

Handsome yet robust in outline, possessed of gustatory excellences unsurpassed by any fish that swims, provided he is not a sufferer from ill-timed methods of *cuisine*, his near relationship to the andromadous salmon of tidewaters is proclaimed in every line and muscle, in spite of deeper colors and more somber markings. His flesh is hard, firm, juicy, and flaky, rich in purple and amethystine hues that pervade even the jaws and teeth, and that, even in life, are but half concealed by the brown and white mottlings of a translucent skin. Few ever taste him in perfection, however, and to be thoroughly enjoyed he must be had fresh from the icy waters of Superior or Northern Lakes Huron or Michigan, and plunged into the pot as near alive as conscience and the dictates of humanity will permit.

While the species is generally denounced as lacking all the essentials that to the mind of the anglomaniac constitute a "*game* fish," the proscription is alike arbitrary and unjust. Varied surroundings inculcate widely diverse habits and dispositions, and a deep-water fish, hooked a hundred fathoms below the surface, perhaps, can scarce be expected to exhibit the peculiar aqueous gyrations and aerial flights of *Salmo salar* as found in some contracted pool and shallow river.

But amethystus is ever an energetic and vigorous foe, requiring the strongest tackle and stoutest arm to manage when in the midst of his long, swinging surges and wonderful rushes, whereby he hopes to free himself of the tenacious barb; and he is a deep and daring fighter, one that when half whipped seemingly is prone to develop tactics most dangerous, and indulge in feats of agility and cunning that will tax to the utmost the ability and strength of the most expert angler. However, we may grant him a fickle and varying disposition, since at one moment he takes the lure with a rush, exhibiting an almost inexhaustible *repertoire* of wiles, when he succumbs only after fierce and prolonged conflict. At another, accepting the hook passively only to be ignominiously dragged from his lair, evincing all the sullen apathy of the catfish.

Usually fierce and bold to a fault, he is a creature swayed wholly by impulse and appetite, possessed of a spirit of investigation that renders him an easy victim to the wiles of man. Eminently piscivorous, he is easily captivated by any strange or unusual object. Here to-day and there to-morrow, he roams the vast expanse of lake to the detriment of the schools of whitefish, ciscoes, and lake herring encountered, for whose flesh he affects the utmost partiality, and which are held in some measure responsible for the superior excellences of his own. Likewise, he feeds to slight extent upon certain pink and red pigmented crustaceans of lobster-like character, from which he is popularly accredited with borrowing his deep amethystine colors, a theory very pretty in abstract, but not at all tenable, since the *siscowit*, a *white-meated* form of trout, derives almost its entire sustenance from this source.

Truly amethystus "lives to eat." Greedy and voracious beyond measure, ever devouring and gormandizing, it matters little what, he is possessed of no epicurean frailties that do not readily succumb to the promptings of curiosity. Rapid and unwearying in journeyings, he frequently follows in the wake of vessels and steamers merely for the delight of feasting upon the refuse of table, pantry, and bar-room, and consequently his stomach is often the receptacle of articles as unique and varied as ever filled the maw of any shark. The disproportion that exists between his epigastrium and visual organs is proverbial, and may best be judged by the following:

During the summer of 1876, while fishing in the east arm of Traverse Bay, Lake Michigan, I hooked a large trout whose stomach, gullet, and jaws were distended to their utmost by another of the same species full half as large, that had been swallowed head foremost, between three and four inches of the latter's tail projecting beyond his nose. Unless the result of accident or a conflict over the bait, I am utterly at loss to imagine *how* he obtained the hook, which was buried deeply in the upper jaw just anterior to the commissure of the lips. Plainly, the lesser fish had but recently been swallowed, as evinced by total lack of digestive disintegration.

Fishermen say he "*bites best when fullest*," an aphorism that is well borne out by a second incident, when a thirty pound fish was had from the deck of a bark in Lake Huron, the contents of whose maw I deemed worthy of a place in my notebook. After the cover of a tin ointment box followed two beef bones, a raw potato, handle of a teacup, a corncob, brass sleeve button with stone setting, rind each of ham and watermelon, cigar stub, "hank" of linen thread, a quartz pebble, piece of glass bottle, lot of orange and lemon peel, suggestive of absorbed cocktails, a ball of human hair (the sweepings of some steamer's barber shop, presumably), several small cinders and coals, and to cap all, by way of dessert, probably, *three ciscoes and a lake herring*—a collection that in point of variety, at least, would not have disgraced the junk shop of a Neapolitan Israelite.

Few true Mackinac trout find their way to market in an unsalted state, owing to the difficulty of catching in summer, since trawls and deep water gill-nets cannot be handled economically. Further, the yellow trout is had in abundance with much less labor and expense, and fairly supplies the demand, very few being aware of the difference. Those that are taken are caught for the most part on hand or trolling lines with gorse bait, and in winter, after the ice has become solid, by means of "snatches" and like ponderous tackle.

Again, this form of trout is rarely had in less than six or eight hundred feet of water, more in twelve and fourteen hundred, the latter being the case off the Fox Islands of Lake Michigan, in many localities among the thirty thousand and odd islands that form the archipelago of Lake Huron and Georgian Bay, and along the north shore of Lake Superior from Michipicoten to Poplar River.

"Snatching" appears as a branch of the art piscatorial unknown save to the Great Lake region proper—at least I am led so to believe—and secures fish that could in no way be had by any other means. Moreover, it frequently yields handsome returns, as two experts working together will oftentimes kill and cure from four to ten barrels of trout per week, that readily command four and five dollars per barrel. Even fifteen barrels have been taken in an exceptionally good locality, but this is deemed fairly phenomenal, and must have entailed no little night as well as day work.

The "*snatch*" as the rude tackle in vogue is denominated, consists of a hook, usually of home manufacture, hammered out from a *three-sixteenths* rod of steel, its shank transfixing in longitudinal diameter a spindle-shaped lead of four or five pounds weight, after which it is turned over into a ring wherein is knotted seventy or eighty fathoms of cotton or hempen line, the primary inception of which was the support of mattresses or drying of newly laundried linen.

With ax and chisel the fisherman opens a hole a yard in diameter through the ice at some point where trout are presumed to abound, usually over or beside some huge reef a dozen or more miles from shore. A slice of raw, fat, salted pork, whose varied odors betoken *anise*, *cummin*, and *rancidity*—a combination supposed to possess irresistible attractions for all fish kind in general, and *amethystus* in particular—is added to the hook, which is then allowed to sink to the utmost depth of its tether in the waters of the lake below; a loop upon the proximate extremity of the line permitting it to slip over the arm, leaving the hands free to seek warmth in situations where it may best be found.

Presently some hungry trout spies the oily delicacy, and finding it to his liking, bolts with a great gulp, then turns leisurely away to seek other equally desirable morsels. But in the mean time his presence has been telegraphed to the other end of the line, and his peaceful reflections are rudely interrupted and jarred upon by a "yank" calculated to bury the barb deep in the tissues of maw or gullet, and in a way that must needs be somewhat demoralizing to the internal arrangements of his amethystine economy; and before he has sufficiently recovered from his astonishment to offer practical resistance, he finds himself ascending swiftly toward the outer air as, with line thrown over shoulder, his captor races away at the very top of his speed, neither pausing nor relaxing until the victim is landed high and dry on the frozen field.

Lake salmon spawn in October and November, the fry appearing coincidently with the disappearance of ice in the spring, when they betake themselves to deep water and hiding in the midst of subaqueous vegetation, that in some localities is so rank as to fairly deserve the title of forests.

From this time on until they reappear as adult fish, nothing is known of their ways or habits. No one has yet been permitted to view either the *smolt*, *parr*, or *grilse* form, unless the latter is represented, as some have surmised, by the yellow trout of these and contiguous waters.

Port Huron, Michigan.

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